OILSEEDS AND OILMILLING IN INDIA

A Cultural and Historical Survey

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Preface

A few years ago I was drawn into studying the history of foods and food plants in India. I had earlier had a long association with the area of oils and fats, and it seemed opportune to marry these interests in a fully-illustrated historical book on the oilseeds of India. I little realised what I had let myself in for. There were times when I almost despaired at the range of the material that confronted me, and there will be many deficiencies in an end-product dealing with so wide a canvas.

The 67 oil-bearing materials chosen for this book have been classed for convenience into 11 categories. Some are historical oilseeds of considerable antiquity, others are more recent introductions into India, and yet others are oleaginous byproducts of crops cultivated as a source of other commodities. These 21 materials are all fairly familiar as sources of oil. The rest however are more or less unique to India. Some are already quite largely exploited in the country for their oil, others are just beginning to enter the picture, and yet others have the potential to do so. Many of these fats are interesting in having either a striking fatty acid and glyceride composition (like the vegetable hard fats), or unusual fatty acid components (like kamala seed oil or chaulmoogra oil), or unique lipid associates (as exemplified by neem oil and karanja oil) that have striking biological activity.

This volume is not a discussion of the current oilseed and oil-milling scenario in India, though this is succinctly summarised in a brief concluding section; nor is modern technology dealt with except in passing. Briefly, this is a book of history and culture centred on oilseeds. Any topic therefore is treated in historical perspective: the oil-bearing materials themselves, their agriculture, marketing and use in daily ritual and medicine, the devices that have been evolved for winning oils from oilseeds, and the outlets, both domestic and utilitarian, for various oils in India. This has meant delving into the enormous wealth of Sanskrit literature (there are an estimated 700,000 manuscripts in the language), into the rich storehouse of Indian folklore and mythology, into archaeological findings and epigraphic records, into history and botany, and into the prolific medical lore of India, both formal and domestic.

A difficulty well-recognised in writing about anything historical in India is the curious reticence shown by writers of the past to factual accuracy. The ancient oilseed-crushing device, the ghani, is hardly ever

mentioned. It is never described, so its mechanical evolution can only be guessed at. The presence of the Greeks in south India in the first and second centuries A.D. is mentioned quite casually in the Tamil literature of the period; it was even considered a figment of the imagination till the discovery about 40 years ago of a Roman trading warehouse strewn with amphorae that still bore the resinous dregs of wine brought there 18 centuries ago. Indian dynasties were established in several countries of South-East Asia since about the start of the Christian era, continuing thereafter for 10 to 15 centuries. Yet, of these momentous events, Indian epigraphs and literature have so little to say that, from perusing the latter, their very existence would not be suspected. In the Yucatan province of Mexico was recently found an inscription dated 923 A.D. in an Indian script, recording the visit there of a ship exploring the coastline and led by an Indian captain named Vusaluna.

In putting this volume together, many organisations and persons have contributed in various ways. The Khadi and Village Industries Commission, Bombay furnished me with literature on modern developments concerning the ghani, and with a very large number of photographs and drawings. From his personal collection, Mr. H.G. Muralidhara of Bangalore placed at my disposal a mass of literature on the collection and utilisation of non-traditional Indian oilseeds. Many librarians allowed me access to their books and journals: those of the Department of Anthropology and of Epigraphy in Mysore, and, in Bangalore, those of the National Dairy Research Institute, the Indian Institute of Science, the Department of Agriculture, the University of Agricultural Sciences, the Mythic Society, the Indian Institute of World Culture and the State Central Library. The National Dairy Development Board made it possible for me to visit certain centres in Gujarat State, like Dwaraka.

The figures and plates that illustrate the book were drawn from many sources. The Khadi and Village Industries Commission, Bombay has already been mentioned; others were the Oil Technological Research Institute, Anantapur; the Central Food Technological Research Institute, Mysore; the Archaeological Survey of India, New Delhi; The Mythic Society, Bangalore; the Indian Council of Agricultural Research and the Indian Agricultural Research Institute, New Delhi. Individuals who kindly furnished illustrations were R.N. Bose, Calcutta, sole executor to the estate of the late Prof. N.K. Bose; Dr. Vishnu-Mittre, Lucknow; G.V. Ramaswami, Valavanur; Sivapriyananda, Mysore, and A. Gautama, Anantapur. One donor wishes to remain anonymous. For many services I am grateful to the photographic sections of the National Aeronautical Laboratory, Bangalore and the Central Food Technological Research Institute, Mysore. Technological Research Institute, Mysore. Special thanks are due to the draftsman who so elegantly visualised my intentions from poor sketches.

I am deeply grateful for three grants which have made it possible to market this book at a lowered price: a substantial donation from the Vallabhdas Vasanji and Smt. Kabubai Vallabhdas Mariwala Charity Trust, and handsome grants from Hindustan Lever Ltd. and Lipton India Ltd.

I can only hope that this volume, treating Indian oilseeds in a cultural and historical setting, will stimulate further interest in this field in future.

Bangalore K.T. ACHAYA

OIL-BEARING MATERIALS OF INDIA TREATED IN THIS BOOK

Common names employed, and current botanical nomenclature

Group A. Historical oil-bearing materials

A1. Sesame	*Sesamum indicum*
A2. Cottonseed	*Gossypium* spp.
A3. Rape-mustard	*Brassica* spp.
A4. Coconut	*Cocos nucifera*
A5. Linseed	*Linum usitatissimum*
A6. Castor	*Ricinus communis*
A7. Niger	*Guizotia absyssinica*
A8. Safflower	*Carthamus tinctorius*

Group B. Newer oil-bearing materials

B1. Groundnut	*Arachis hypogaea*
B2. Soybean	*Glycine max*
B3. Sunflower	*Helianthus annuus*
B4. Oil palm	*Elaeis guineensis*

Group C. Oil-bearing materials derived as byproducts of cultivated crops

C1. Ricebran	*Oryza sativa*
C2. Tapioca seed	*Manihot esculenta*
C3. Maize germ	*Zea mays*
C4. Tobacco seed	*Nicotiana* spp.
C5. Rubber seeds	*Hevea brasiliensis*
C6. Tung seeds	*Aleurites* spp.
C7. Jute seeds	*Corchorus* spp.
C8. Spent coffee grounds	*Coffea* spp.
C9. Tea seeds	*Camellia* spp.

Group D. Oilseeds with unusual lipid associates

D1. Neem	*Melia indica*
D2. Karanja	*Pongamia pinnata*
D3. Kusum	*Schleichera oleosa*
D4. Nahor	*Mesua ferrea*
D5. Undi	*Calophyllum inophyllum*
D6. Rayana	*Amoora rohituka*

Group E. Oilseeds carrying vegetable hard fats

E1. Mahua	*Madhuca indica*
E2. Sal	*Shorea robusta*
E3. Dhupa	*Vateria indica*
E4. Kokum	*Garcinia indica*
E5. Tamal	*Garcinia morella*
E6. Phulwara	*Diploknema butyracea*

Group F. Oilseeds carrying soap-making oils

F1. Khakan-Pilu	*Salvadora* spp.
F2. Pisa	*Actinodaphne hookeri*
F3. Chirandi	*Litsea glutinosa*

Group G. Oilseeds with oils of unusual nature

G1. Maroti	*Hydnocarpus laurifolia*
G2. Kamala	*Mallotus philippinensis*
G3. Pinari	*Sterculia foetida*
G4. Malkanguni	*Celastrus paniculatus*

Group H. Oilseeds from shrubs

H1. Ratanjyoti	*Jatropha curcas*
H2. Gokhru	*Xanthium strumarium*
H3. Hurhur	*Cleome icosandra*
H4. Somraji	*Vernonia anthelmintica*
H5. Argemone	*Argemone mexicana*

Group I. Oilseeds from trees that yield other commercial products

I1. Akra	*Calotropis* spp.
I2. Simul	*Bombax ceiba*
I3. Kapok	*Ceiba pentandra*
I4. Baheda	*Terminalia belerica*
I5. Palas	*Butea monosperma*
I6. Teak	*Tectona grandis*
I7. Tamarind	*Tamarindus indica*

Group J. Oilseeds from fruits

J1. Mango kernel	*Mangifera indica*
J2. Thumba	*Citrullus colocynthis*
J3. Water melon	*Citrullus vulgaris*
J4. Musk melon	*Cucumis melo*
J5. Lime	*Citrus aurantifolia*
J6. Sweet orange	*Citrus sinensis*
J7. Papaya	*Carica papaya*
J8. Sitaphal	*Annona squamosa*
J9. Sapota	*Manilkara achras*
J10. Grape	*Vitis vinifera*
J11. Kapittha	*Limonia acidissima*

Group K. Oils from vegetables

K1. Ambadi	*Hibiscus cannabinus*
K2. Okra	*Abelmoschus esculentus*
K3. Tomato	*Lycopersicon lycopersicum*
K4. Chilli	*Capsicum annuum*

INDIAN CHRONOLOGY

LITERARY		HISTORICAL	
Munda (aboriginal) languages	Before 2000 BC	Munda and Nāgā tribes	Before 2000 BC
Indus Valley language (undeciphered)	2500—1500 BC	Indus Valley (Harappan) towns:	
Sanskrit works:		Mohenjodaro	2500 BC
Rigveda	1500 BC	Harappā	to
Atharvaveda, *Yajurveda*, *Brāhmanas*	1000— 800 BC	Chanhudaro	1500 BC
Upanishads		Lothal	
Various *Sūtras*	800—300 BC	Kālibangan	
Pānini's grammar	600 BC	Entry of Āryans in waves through	
Buddhist canon, Jātaka tales	500—300 BC	the northwest	From 1700 BC
Purānas	From 500 BC,	Protohistoric culture sites:	
	and for 15	Navdatoli/Maheswar	2000—1400 BC
	cents. thereafter	Chirand	2000—1300 BC
Mahābhārata, in which is	500 BC—400 AD	Inamgaon	1600— 700 BC
included the *Bhagvad Gita*		Atranjikhera	1500— 200 BC
Ramāyana	400 BC—200 AD	Nevasa	1300 BC
Susruta Samhitā	400 BC—400 AD	Ahichchhatra	—
Charaka Samhitā	400 BC—400 AD	Buddha's life	563— 483 BC
Kautilya's *Arthashāstra*	300 BC	Alexander's conquest	327— 325 BC
Manusmriti	200 BC—200 AD	Megasthenes	c. 320 BC
Yāgnavalkya Smriti	100 AD—300 AD	Ashoka the Great	273— 232 BC
Kālidāsa's plays	450 AD		
Someshvara's *Mānasollāsa*	1137 AD		

Tamil literature:	
Tolkāppiyam	1st cent. AD
Puranānooru	2nd cent. AD
Nāladiyār	7th cent. AD
Greek writers/works:	
Writers accompanying Alexander	327 BC—325 BC
Strabo	65 BC— 25 AD
Pliny	23 AD— 79 AD
Periplus Maris Erythraei	1st cent. AD
Chinese pilgrim-writers:	
Yuan Chwang	629—643 AD
I-tsing	671—695 AD
Muslim writers:	
Al-Biruni	1030 AD
Ibn Battūta	1342 AD
Abul Fazl's *Aīn-i-Akbari*	1590 AD
European writers:	
Marco Polo	1293 AD
Garcia da Orta	1563 AD
Linschoten	1598 AD
Mandelslo	1638 AD
Niccolao Manucci	1680 AD
Van Rheede	1686 AD
Ovington	1689 AD
Alexander Hamilton	1727 AD
William Sleeman	1840 AD
George Watt	1888—1908 AD

Discovery of the monsoon seasonal winds to India by Hippalus	45 AD
Extensive trade between South India and the Roman Empire	1st and 2nd cents. AD
Hindu dynasties established in several countries of South-East Asia	From 1st cent. AD onwards, up to the 14th cent. AD
Gupta empire	320—500 AD
Emperor Harshavardhana	606—647 AD
Early Muslim kingdoms:	
Arab rulers in Sind	712—1001 AD
Raids into west and North India	1001—1260 AD
Turkish and Afghan sultans	1260—1526 AD
The Moghul empire:	
Babar	1526—1530 AD
Akbar	1556—1605 AD
Jahangir	1605—1628 AD
Aurangazeb	1658—1707 AD
Vasco da Gama's landing in south India	1498 AD
Transfer of flora from South America and Mexico to India	16th and 17th cents. AD
Battle of Plassey	1757 AD
British rule in India	1757—1947 AD
Mahatma Gandhi	1869—1948 AD
Indian Independence day	15 August 1947

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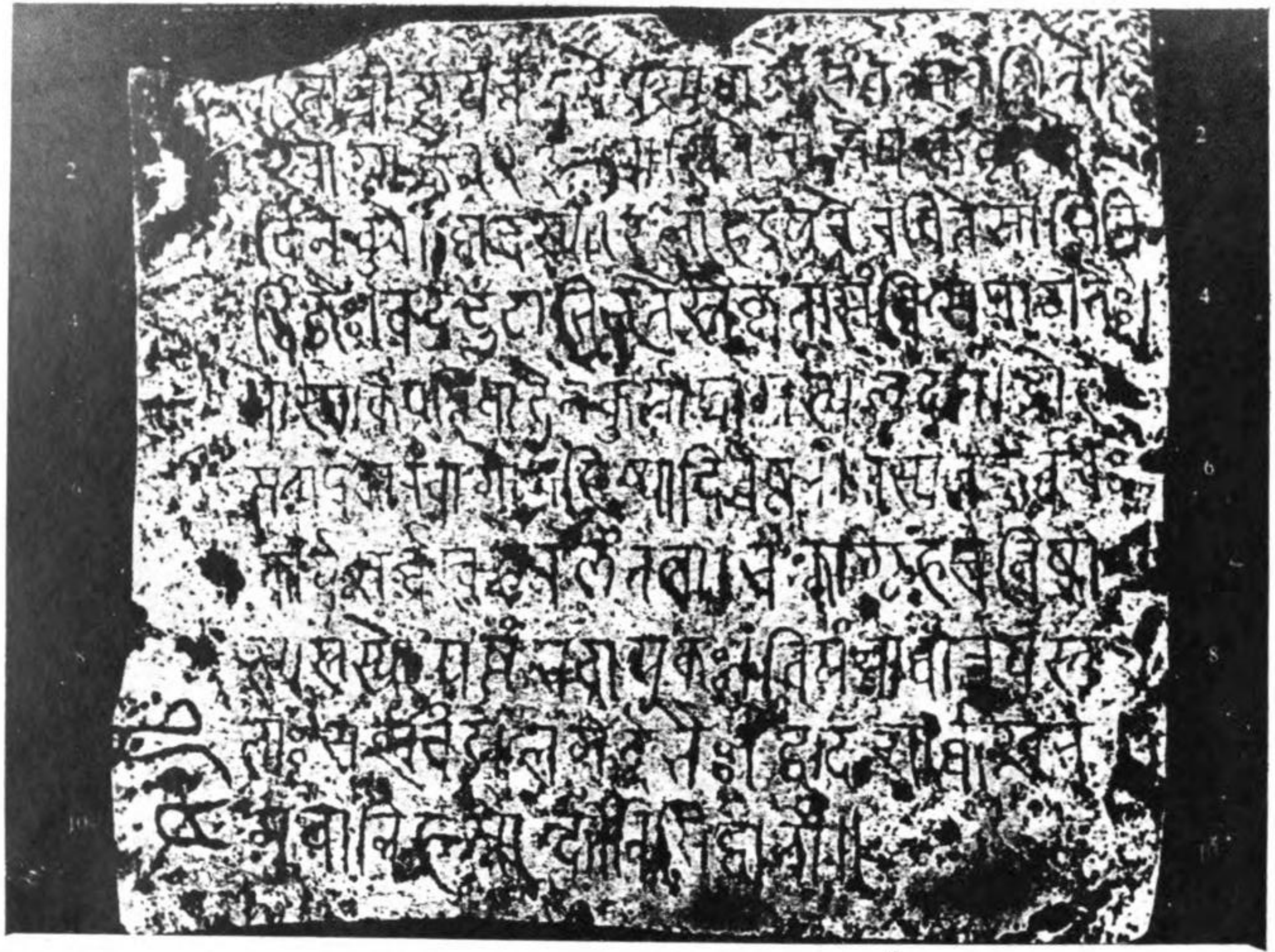

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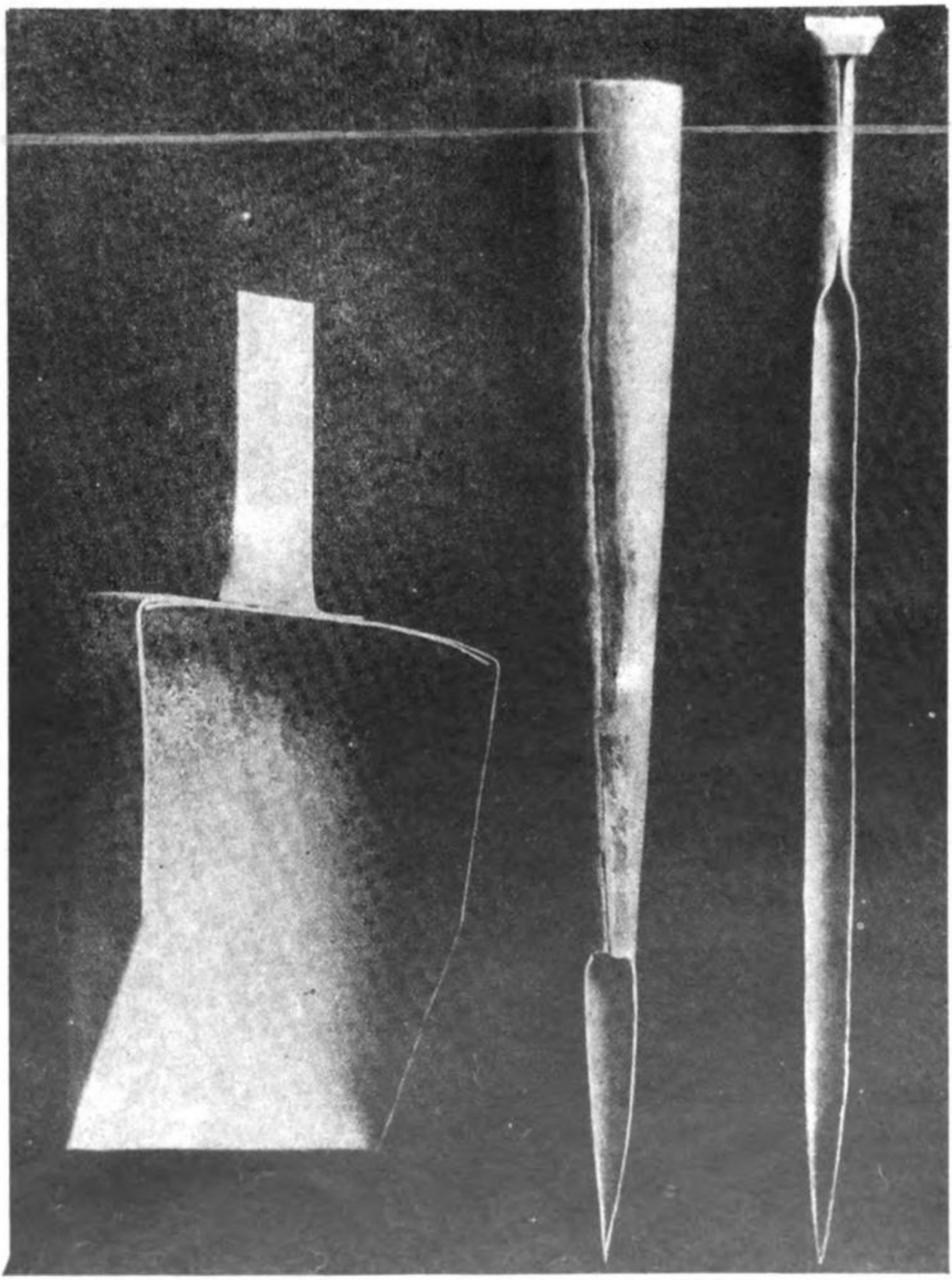

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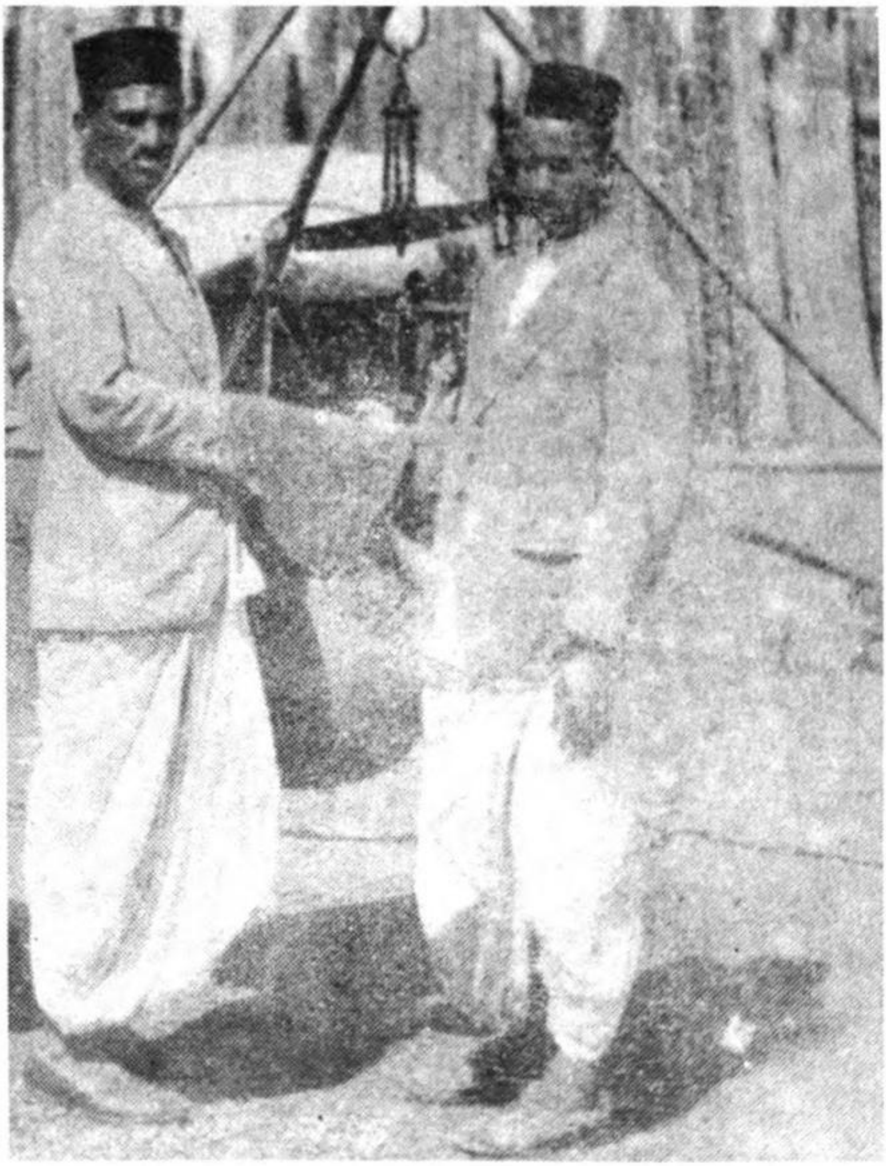

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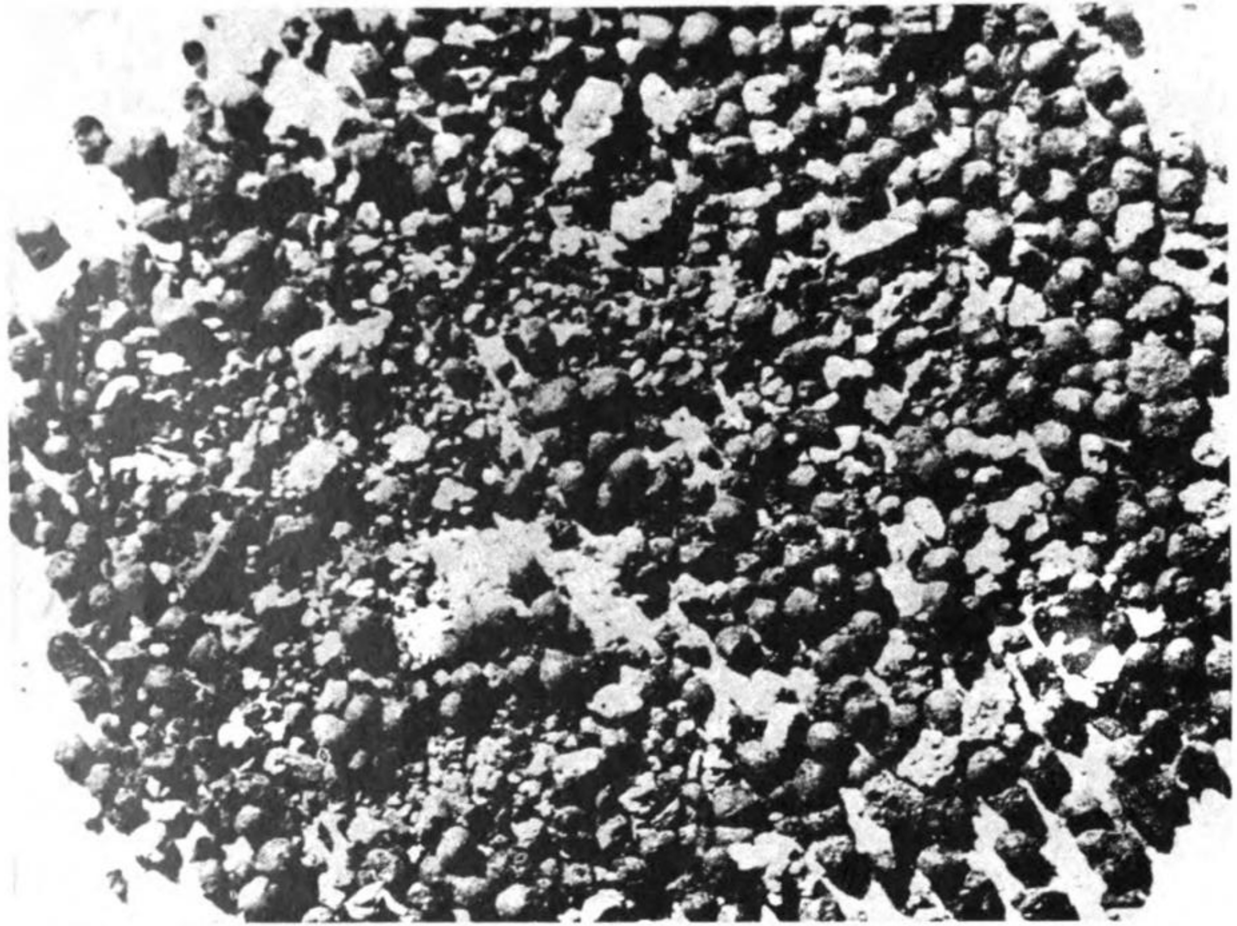

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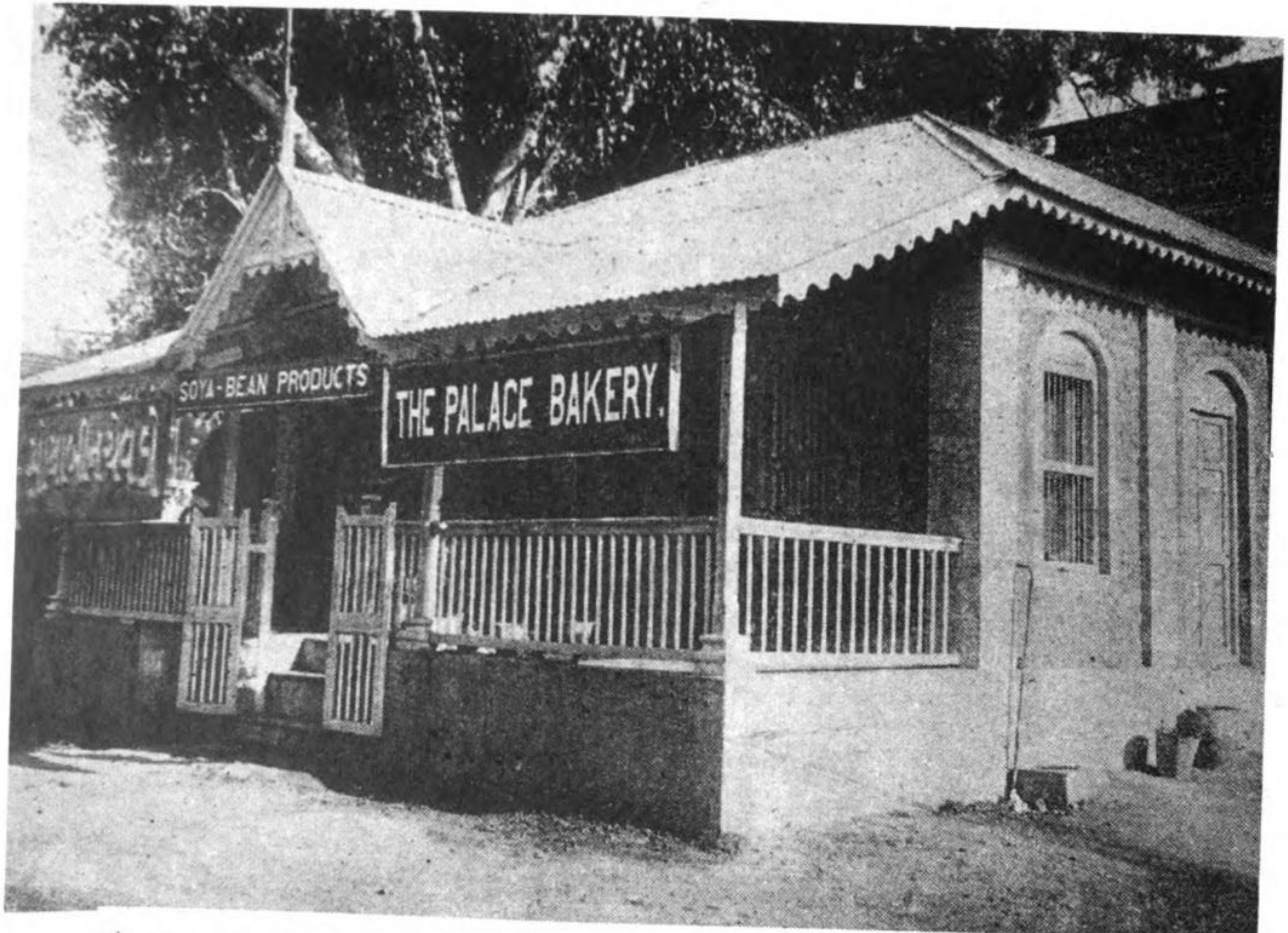

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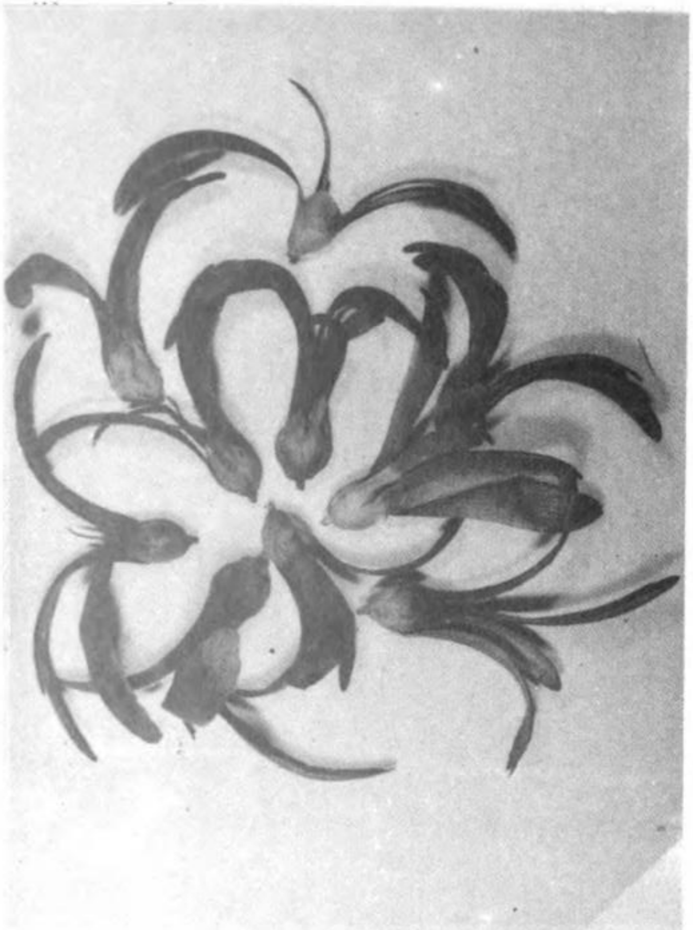

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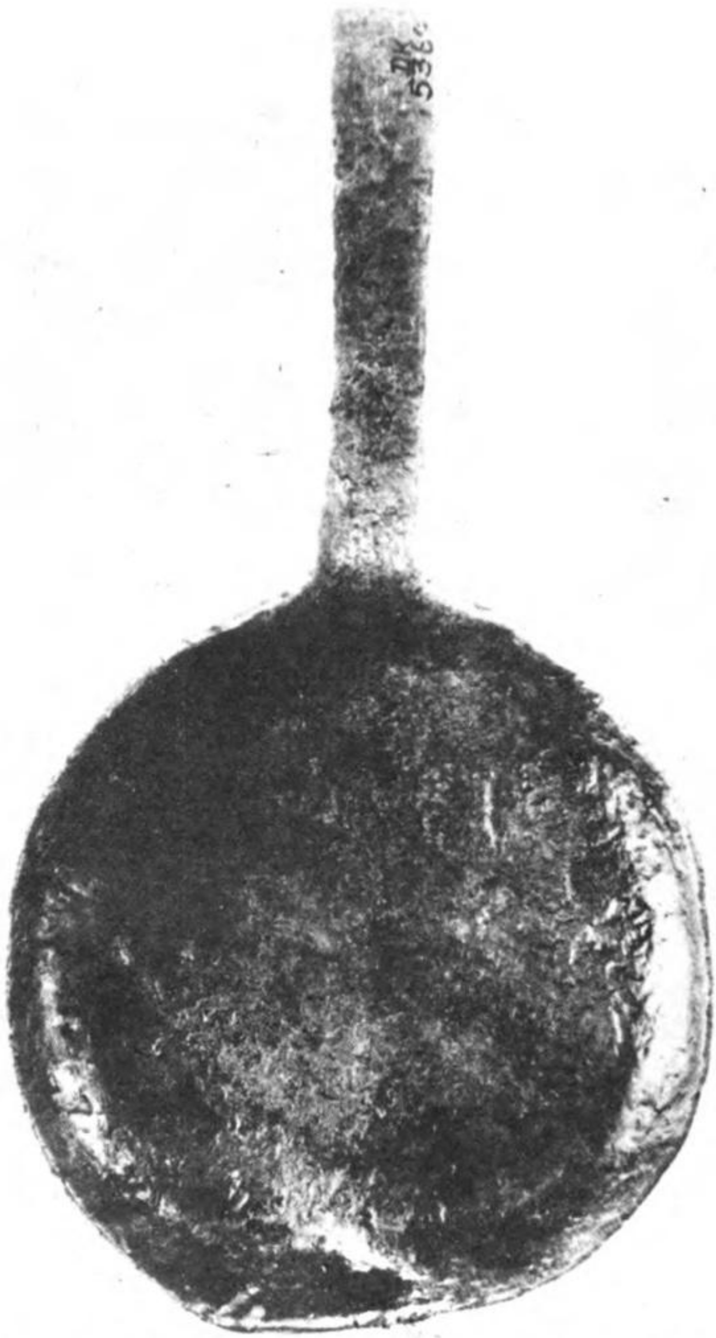

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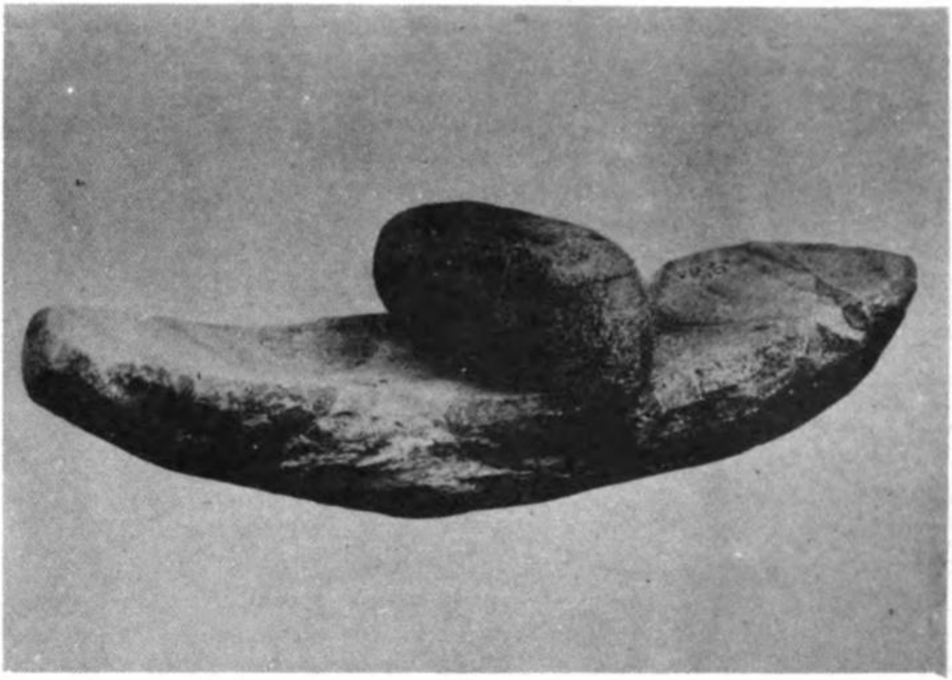

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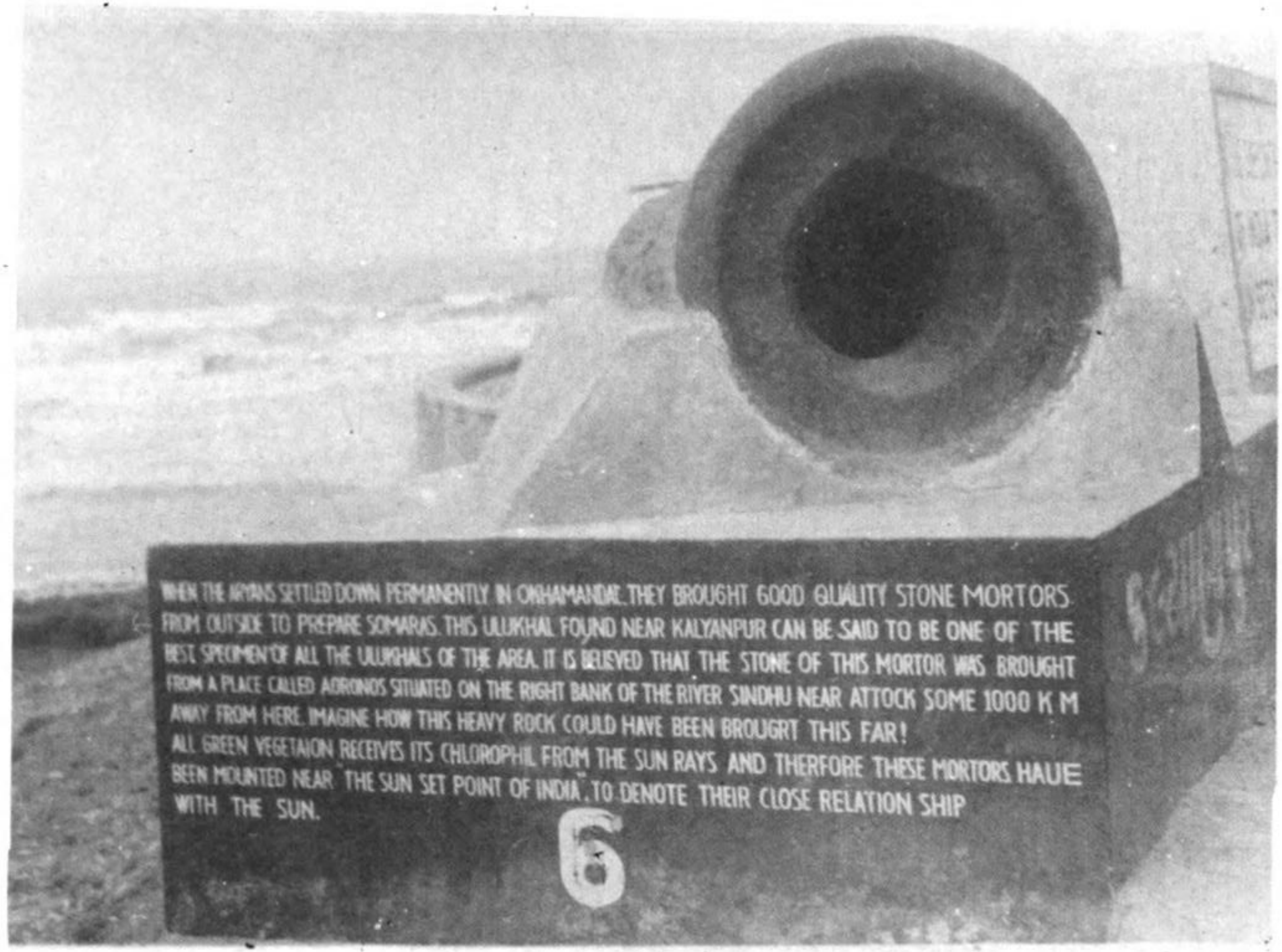

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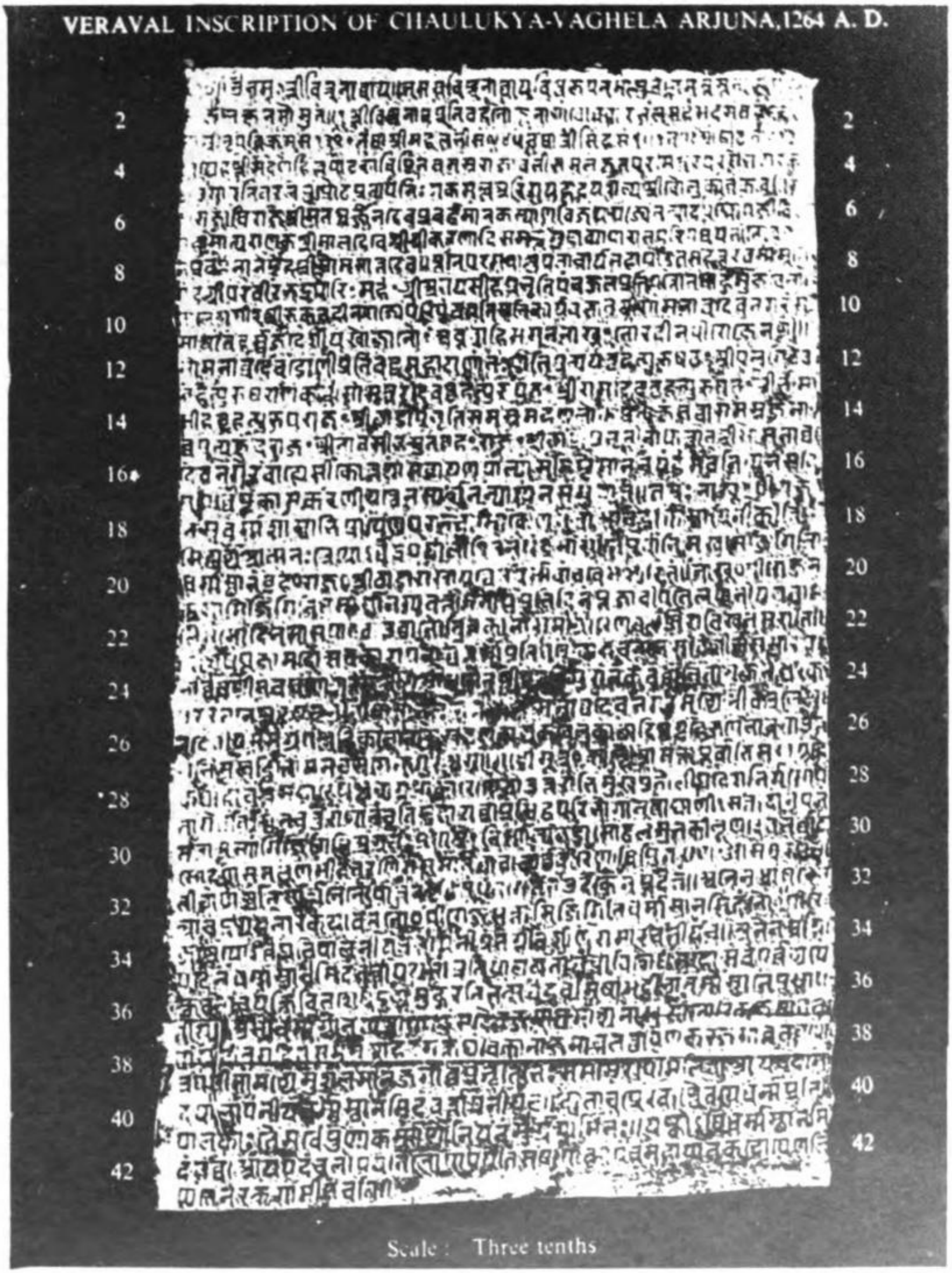

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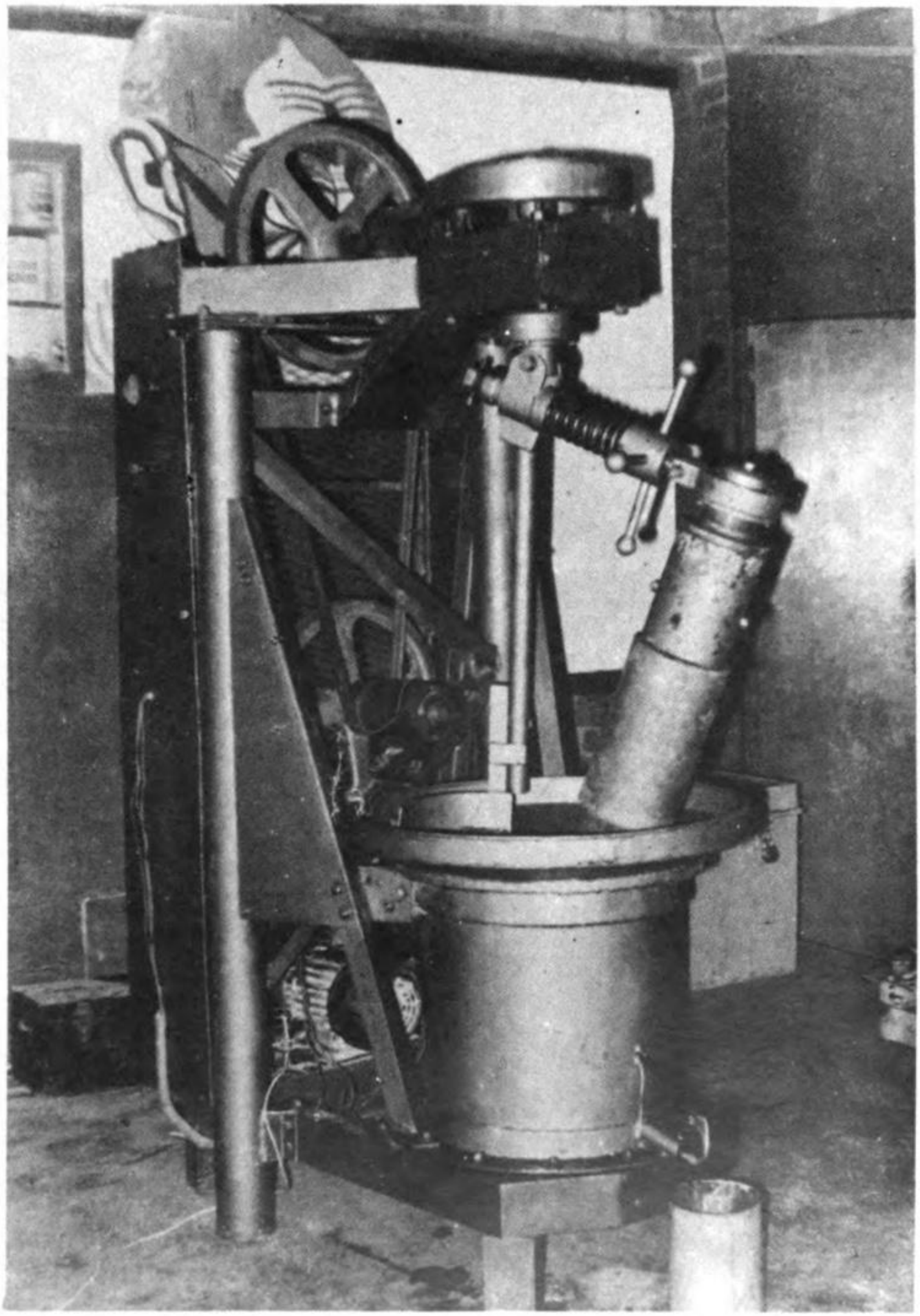

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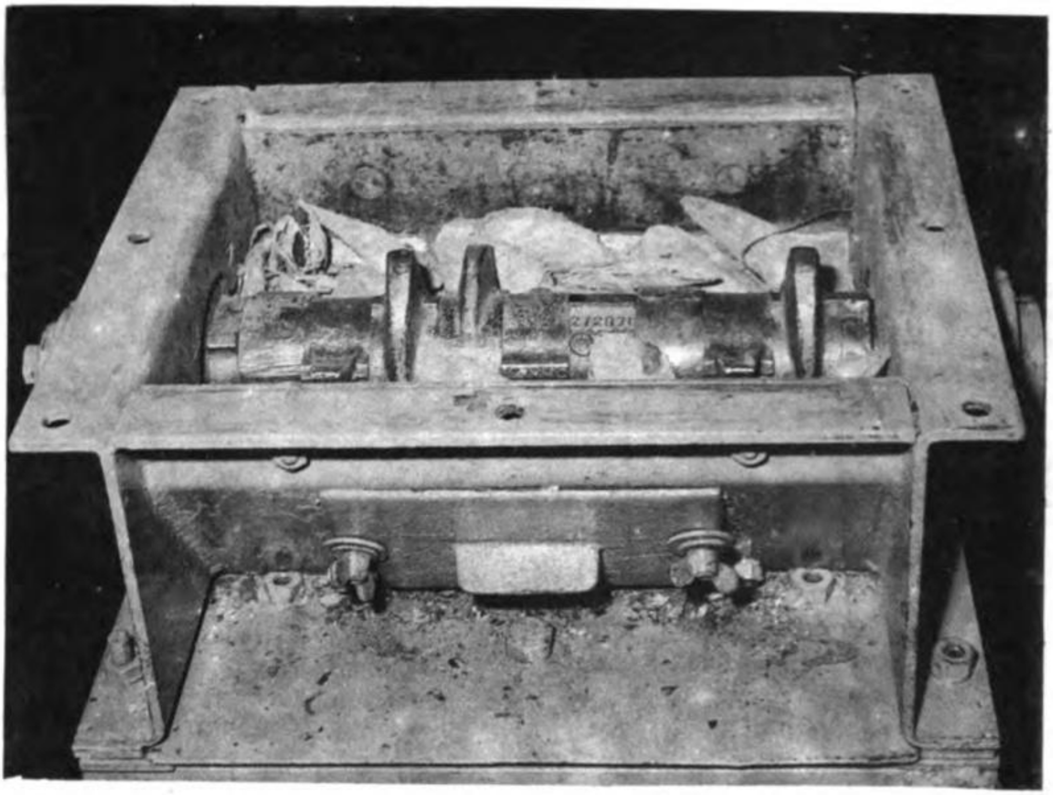

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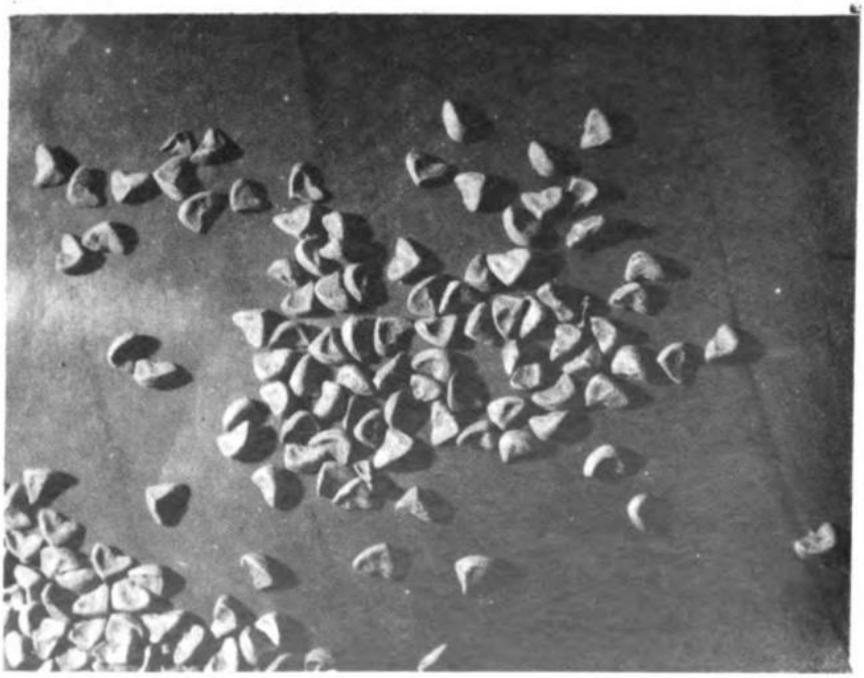

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PART A

OILSEEDS

CHAPTER 1

Agriculture in India's History

1.1 Food in Prehistory

The great apes from whom man is descended were vegetarian, but when he adopted an upright stance man became omnivorous. This started some 10 million years ago, when *Ramapithecus punjabicus* lived in north India. This prehominid may have been indigenous, or may have migrated from Africa by the land links that then existed.[1a] To outwit the prey that he used as food, early man needed strength, cunning and implements like stones and clubs. These were evolved in a series of phases.[1b] First came the huge, blunt chopping tools from the primitive food-collecting stage (about 500,000 to 300,000 BC), of which typical examples have been found in the Siwalik hills around Chandigarh and Shimla, in Jabalpur in Madhya Pradesh, and along the river valleys of south India.[2] The next stage of development is the advanced food collecting stage (from about 20,000 to 10,000 BC), during which the tools were pointed stone ovals of various kinds for use as hand axes, digging tools, scrapers and knives. These yielded, during the next period of incipient food production, to sharp stone chips called microliths which, tipped to an arrow or a spear, extended the hunting power of man.

Striking graphic evidence of this type of life has come to light by the discovery in Bhimbhetaka, about 42 km from Bhopal (Madhya Pradesh), of a series of rock shelters on the Vindhyan hills.[1c,3] Nearly 500 of these carry wall paintings, and the floor when dug up revealed stone and bone tools that were evidence of continuous occupation from about 500,000 to just 2,500 years ago. The paintings themselves were dated from about 20,000 years ago (Fig. 1). The earliest are in green and dark red earth colours, and depict dancers and hunters in fine outline, besides the elephant, bear, tiger and rhinoceros. The later groups frequently show hunting scenes using barbed spears, pointed sticks, and bows and arrows, with a variety of birds and animals as victims. Human activities of love, pregnancy, birth and burial are realistically and economically conveyed. These tools and drawings confirm that meat of many kinds was consumed, doubtless supplemented with gathered food such as honey, roots, leaves, fruits

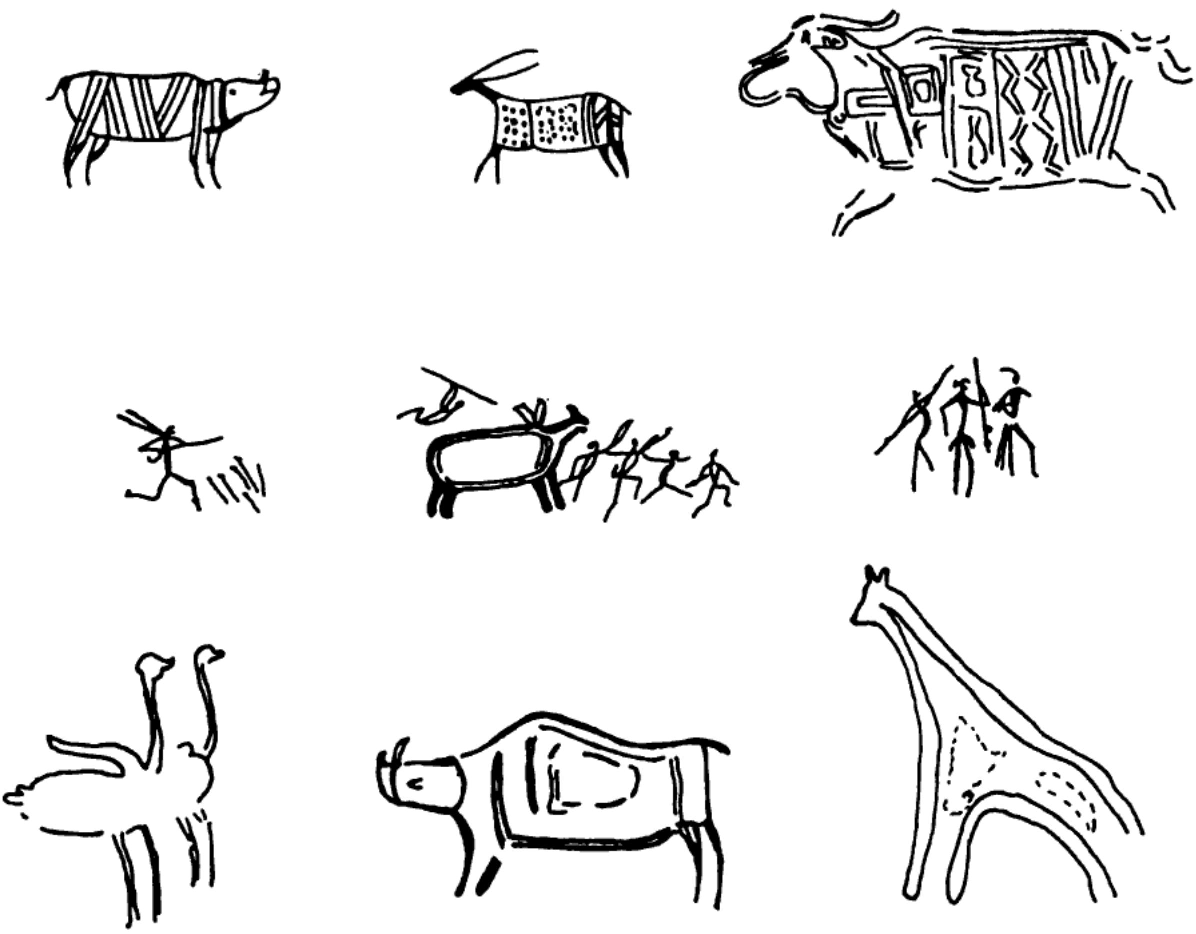

Fig. 1. Assorted prehistoric drawings from the Bhimbhetaka caves in Madhya Pradesh (Source: After V.S. Wakankar)

and vegetables. These practices are followed even today by many tribal forest dwellers of India who practise no agriculture, or are only rudimentary agriculturists.

1.2 The First Agriculture

Living in settled villages and cultivating domesticated plants and animals gives rise to tools like scythes, axes and pottery. Querns for grinding, and the use of fire and of animal power, commenced about 5000 BC in the rich 'fertile crescent' area of the Middle East, a tract that sweeps in an upward arc over the top of Arabia, and below the Caspian Sea from Jordan to Iran and Iraq. From here the practice of agriculture could have radiated in various directions, for example from Iran by way of Afghanistan to the north-west of India. Excavated settlements in Kile Gul Mohommad and Mehrgarh,[4] both near Quetta in Pakistan, are clearly links between the practices of the Middle East, and those that were to blossom out later in north-western India as the Indus Valley or Harappan civilisation, a culture that lasted for 1,000 years, from about 2500 to 1500 BC.

1.3 The Indus Valley Civilisation

CITIES AND TOWNS

Harappa, high up on the river Ravi, and Mohenjodaro, lower down, are 560 km apart (Fig. 2). They were the twin metropolises of this civilisation, of which some 40 towns have been laid bare.[1d] Chanhudaro is another settlement even further down, and the culture runs into Gujarat, where the port town of Lothal, slightly north of the Gulf of Cambay, and Rangpur, about 48 km south-west of Lothal, are the largest of some 30 settlements. These have been excavated from about 1921 onwards to reveal an extraordinary pattern of life.[5-8]

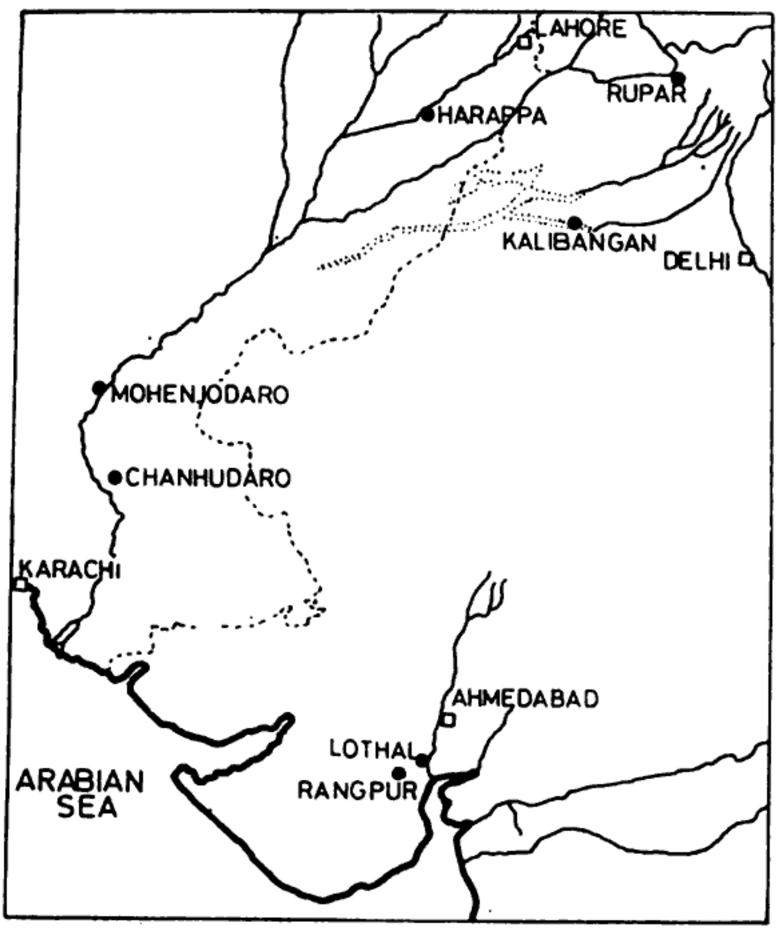

Fig. 2. Map showing major Indus Valley settlements (2500-1500 BC)

All towns were built to a grid pattern, with straight avenues and smaller side streets. Houses were of baked bricks of standard dimensions, and graded weights and measures were likewise standard. Seals used for trading purposes carried magnificent representations of animals, figures, trees and a uniform script (which is still undeciphered). The town of Lothal boasted of an oblong enclosure, 222 by 37 m with a sluice gate, which is believed to have been a shipping dock where vessels from Egypt and

Mesapotamia were berthed.[9a] Gemstones, ivory, carnelian beads and cotton goods from the Valley were exchanged for metals like copper, tin and gold, and perhaps wool.[10,11]

Food and Agriculture

Apart from cattle, poultry and fish as items of food, archaeological excavations have unearthed wheat, barley, several pulses, peas and fruit.[12] Two oilseeds were found. One was a lump of charred sesame from Mohenjodaro, and the other a lot of carbonised rape-mustard seeds from Chanhudaro.[12a] The coconut palm is believed to be represented on an earthen bowl recovered from Harappa, and a piece of jewellery found there resembles the coconut itself.[13]

What is there by way of agricultural evidence, apart from the seeds that were found? Ploughs being of wood are perishable, but a clay model of a plough, some 20 cm long, was found at Mohenjodaro.[1a] Another remarkable find was made in Kalibangan in western Rajasthan, about 310 km north-west of Delhi.[14] The people of Kalibangan had developed agriculture prior to 2450 BC, even before the advent of the Harappan culture. What excavation revealed was no less than the earliest ploughed field found anywhere in the world, showing one set of wide-spaced ploughed furrows running east-west, and another, more closely set, at right angles to the first. Short gram shrubs and taller rape-mustard plants are grown in exactly the same way in the area even today, to ensure that the shadows of the latter do not cut off sunlight from the low-standing gram shrubs. Superimposed over this field was the later Harappan city.

A clay seal from the Harappan city of Lothal carries a curious pattern of holes in rows above a rake-like structure.[1a] This has been identified by its discoverer as a seed drill, though the interpretation is somewhat conjectural.

Carts were in use in various Indus Valley cities even at the very start.[1a] Children's toys from Mohenjodaro, Harappa and Lothal all show carts with solid wheels; some have a superstructure of wooden posts and others of wicker troughs, both of which occur in India to this very day. Bronze models of carts have also been found in Harappa and Chanhudaro. The originals must have been pulled by cattle or buffaloes; many types of these animals are sculpted as toys or depicted on seals, and conform closely to named breeds of the present.

Perhaps most remarkable of all the agricultural artefacts were the magnificent granaries for grain storage found at three large Indus Valley cities. The granary at Harappa was the largest, and consisted of a raised platform about 1.2 m high and 52 by 42 m in size, on which stood two identical granary blocks about 7 m apart.[5] Each block had six chambers, with corridors between them opening only on the outside, and approached by a short flight of steps. Each chamber was divided into four storage spaces by full-length walls and the floor was raised off the ground and

rested on sleepers. Air could circulate in the void below, and enter the chambers for aeration through small triangular vents. The granary faced the river, by which the grain may well have arrived. At Mohenjodaro, the massive granary was probably of wood, which had naturally disappeared when excavated.[15] Some 27 storage blocks of bricks, set on a high brick base with sloping walls, were arranged crosswise to ensure air circulation. Half-way up the brick citadel was a loading platform, from which doubtless bags of grain were handed up from carts standing in the niche below. At Lothal, the mud-brick platform was 3.5 m high and 51 by 45 m.[9b] On 12 cubical brick-made blocks probably rested the vanished wooden granary superstructure, each block being 3.7 m square and a little over a metre high. Melted material found inside suggested that the wooden structure must have burnt down.

Adjoining the granary at Harappa was a line of 17 circular brick platforms.[16] The bricks were placed on edge, fanning out from a central hole. The presence of straw, husk, burnt wheat and dehulled barley in the crevices showed clearly that these were mortars in which grain was pounded using long wooden pestles, as is still the practice all over India.

Saddle querns were employed for grinding grain in the home. Pounding mortars were also found in Mohenjodaro and Harappa, some of them worn down even 12 cm by constant use.[1e] At Mohenjodaro and Lothal were found circular grinding stones in two pieces, such as are still used for coarse or fine grinding. The grain is fed through a central hole in the upper stone, which is rotated against the stationary lower stone by means of an upright wooden handle fixed on the periphery. The capacity is much higher than for mortars, and operation is nearly continuous.

Crops appear to have been raised at all the Indus Valley sites by exploiting the annual flood inundations along natural river channels. Only a little surface ploughing was required.[12] Wheat and barley were sown after the inundation had subsided, and the harvest reaped the following March and April, thus constituting the typical *rabi* crop of the present. *Kharif* or the monsoon crops, like cotton and sesame, would be sown at the beginning of the inundation and harvested at its close, in the autumn.[1e] Alternatively, along river banks, the land might be lightly ploughed, the seed sown and the soil smoothened down using a plank. That water wheels were used to lift water is suggested by the very large numbers of roughly-made pottery jars with deep grooves around the middle found at Mohenjodaro.[17] Such water wheels are still in use in India.

Trade

There is considerable evidence of trade between the civilisations of the valleys of the Indus and the Euphrates in Iraq.[10,11] India exported barley, sesame (se-gis-i) and linseed (i-gis) oils, cotton, cane and a variety of woods, ivory, gems and stones, pigments, and gold and copper. What it

took in return was possibly mainly copper, tin and gold. Settlements of Indian traders seem to have existed in Mesapotamia for monitoring these transactions.[8]

Many Harappan cities show signs of having come to an abrupt end.[8] Mohenjodaro, on radio-carbon dating, shows a sudden halt about 1750 BC. Lothal, tne port town in Gujarat, after repeated floods and rebuilding, finally came to an end about 1900 BC.[9c] The Punjab area is notorious for the changing course of rivers following tectonic movements, and several simply seem to have disappeared or dried-up leaving waterless beds. As the Rann of Kutch, which formed the estuary of the Indus Valley system, silted up into a marsh, the Harappan civilisation, so dependent on water and estuary, rapidly declined.[12b] There is evidence of violent invasion, and of fleeing people being struck down and carrying the marks of weapons; whether this was from the waves of nomads called the Aryans who poured into India can only be conjectured.[18] There is some evidence of continuity in practices, knowledge and even language between the Harappan culture that died, and the new Vedic civilisation that was to follow, first in the North of India, then in the Indo-Gangetic plain and later throughout the country.

1.4 Early South Indian Agriculture

Tools of the Old Stone Age from about 250,000 years ago have been found in the southern plateau, which is called the Deccan, and those of the Middle Stone Age, termed the mesolithic, at various sites in Andhra Pradesh and Karnataka.[19a] Polished stone axes characterise the southern neolithic culture, which appeared to have started about 2300 BC, gradually yielding to typical microliths and eventually to the use of metals.[20] Indeed iron usage may have started as early in the south as it did in the north, which was about 1000 BC, and the usual intermediate copper stage may perhaps have been bypassed in south India.[21,22] By 2300 BC, Brahmagiri in Karnataka has provided clear evidence of agricultural food production.[23] At about the same period, 2160 BC by radio-carbon dating, there appear to have existed all over south India a class of professional cattle-keepers, with herds of 600 to 1,000 animals tended in pens.[24] The dung that accumulated was periodically burnt to provide great mounds of ash. By 1800 BC or so, apart from meat and milk, excavations at several places reveal an agricultural way of life. Several foodgrains were raised under difficult dry conditions, like millets and hardy pulses.

Slightly further north, in the valleys of the rivers Narmada and Tapti which flow into the sea north of Bombay, a series of settlements dated around 1500 BC have been excavated: Nevasa, Navdatoli and Inamgaon.[1f] Navdatoli yielded carbonised linseed (1600 BC) and Ter a carbonised castor seed.[25a] The latter was in a strata dated at only 150 BC to 100 AD. along with a number of other hardy millets and pulses.

1.5 The Vedic Period

Sources

If knowledge of the earliest phases of Indian history and agriculture is through archaeological excavation, when one comes to the Vedic period literary evidence takes over. The Aryans are believed to have been a nomadic and aggressive people who had dwelt during the middle of the third milleniun BC in the steppe regions of south-east Europe, from the Ural mountains to the river Dnieper.[26] Fanning out in waves from there under geographical and climatic stresses, the Aryans swarmed all over Europe, then southward to Iran and eventually into India. Most of these incursions occurred through the north-west Indian passes, but it seems likely that other waves of Aryan immigrants also entered across the Himalayan ranges into the fertile plains of the river Ganges.[27a] European philologists like Max Mueller were struck by the linguistic similarities: "Sanskrit, as compared to Greek and Latin, is an elder sister, not a parent."[28a] And again: "Sanskrit, the ancient language of the Veda, is no more distinct from the Greek of Homer, or from the Gothic of Ulfilas, or from the Anglo-Saxon of Alfred, than French is from Italian. All these languages together form one family, one whole."[28b]

The earliest literary offering of the new Aryans was the *Rigveda*, a collection of 1028 hymns in mandalas (classes) dated at about 1500 BC.[29a] The Vedic hymns were "preserved entirely by memory, but by memory kept under the strictest discipline,"[30a] transmitted unblemished from those times to the present, to be committed to paper only recently. They are rich if unconscious sources of information about the foods, food beliefs and agricultural practices of these early people. So is the *Yajurveda*, a prayerbook of mantras to be recited at various sacrifices by a priest, and composed about 800 BC. The *Atharvaveda* of a similar date has 731 hymns: many of them are simply drawn from the *Rigveda*, and embody charms against maladies, accompanied by the use of prescribed herbs and dietary injunctions.

Each *Veda* was accompanied by its own *Brāhmanas*, books of prayer which relate the ritual to the sacred text, and at the end of each are the *Āranyakas* (first books), explaining the mysticism and symbolism of sacrifice. The *Upanishads* are philosophical writings attached to each *Veda*.[31] All were composed before 800 BC.

From among later Sanskrit works, some may be singled out for the present purpose. The *Sūtras* consist of six manuals of instruction in various disciplines. The Sanskrit grammar of Panini has been described as "a natural history of the Sanskrit language",[29b] and is dated 600 BC. The Buddhist canon (500 to 300 BC) includes the *Dhammapada* or book of ethics, and the *Jātakas*, some 500 stories of incidents in the life of the Buddha in his numerous previous incarnations, with fascinating incidental information on the social and economic ethos of the time.[27b,32,33] Max Mueller writes: "What would Plato and Aristotle have said, if they had

been told that at their time there existed in India, in that India which Alexander had just discovered, if not conquered, an ancient literature far richer than anything they possessed at that time in Greece?"[30b]

Of later works, a few deserve mention. The epic *Ramāyana* was originally written about 400 BC, with accretions in the first two centuries of the Christian era. The other epic, the *Mahābhārata*, was composed later, and has also many accretions over the original tale of about 350 BC. One of its chapters is the great *Bhagavad Gita*, a manual of ethical conduct. The *Arthasāstra* is a manual of statecraft written about 300 BC by Kautilya.[34] He is credited with bringing to the throne the Emperor Chandragupta Maurya by defeating the Greek governor Seleukos Nikator, who had tried to emulate Alexander the Great in conquering India. The Institute or Code of Manu, a digest in 2,685 verses of the laws and creeds current about 100 BC (though perhaps originally written earlier) is called the *Manusmriti*.[29c]

Two other works specially concern food materials.[35] One is the medical text of Charaka, originally placed in the sixth century BC, but so frequently interpolated later that the *Charaka Samhitā* now available is placed at only about 100 BC. So too the *Susrutha Samhitā*, the surgical text, originally also of the sixth century BC, but considered some 10 centuries later in its present redaction. How much of the matter of these texts is original, and what material has been added later, is difficult to say. All these works, whatever their basic purpose, have invaluable allusions to oilseeds, their agriculture and their processing.

Agricultural Practices: Vedic Injunctions

Quotations from these literary works will serve to show the style and form of Aryan agriculture between 1500 and 1000 BC.[22,36,37]

Profession of agriculture: "Play not dice; pursue agriculture; delight in wealth so acquired, there, gambler, are cows, there is a wife (to be looked after)" (*Rigveda*).

"Let the oxen draw happily; the men labour happily; the plough furrow happily; let the traces be bound happily, and the goad be plied happily" (*Rigveda*).

Crops: "May for me prosper, through the sacrifice, milk, sap, ghee, honey, eating and drinking at the common table, ploughing, rains, conquest, victory, wealth, riches. May for me prosper, through the sacrifice, low-grade food, freedom from hunger, rice, barley, sesame, kidney beans, vetches, wheat, lentils, millets, panicum grains and wild rice. May for me prosper, through the sacrifice, trees, plants, that which grows in ploughed land, and that which grows in unploughed land" (*Yajurveda*).

"I offer you dried sugarcane, white sesamum, reeds and bamboo" (*Atharvaveda*).

"Taste the ghee, and the oil of the sesame" (*Atharvaveda*).

"Eat the rice, then the barley, then the blackgram, and then the sesame" (*Atharvaveda*).

Seasons: Six seasons (ritus) were distinguished: vasanta, grishma, varsha, saradrithu, hemantharithu and shashi. Solar and lunar years were differentiated. The coming of the rains was hailed with joy as the time of renewal.

Water: "Let not...our cattle...be hurt by falling into a well" *(Rigveda).*

"As a thirsty ox, or a thirsty man, hastens to a well..." *(Rigveda).*

"Arrange the buckets in their place, securely fasten them on with straps: we will draw water from this unfailing well. Set up the cattle trough, let us pour out the water from the unfailing well" *(Rigveda).*

"The water spread over low places" *(Rigveda)* can mean either irrigation or inundation.

"Flow here, just here O mighty streams, whither I am now leading you" *(Rigveda)* suggests that irrigation was practised.

"Rivers, the corroders of their banks, like armies destructive of their foes" *(Rigveda)* refers to soil erosion.

A complete list of all water sources is given *(Yajurveda).*

Fields: "Like a field measured by a rod" *(Rigveda).*

"Wide fields, vast treasures, spacious pastures, has Indra bestowed on his friends" *(Rigveda).*

Good and bad lands are noted; a barren field is compared to a bald head!

Sowing and harvesting: "Sow the seeds; may the earheads be many and heavy for the sickles to cut and pile in heaps; may these auspicious ploughs bring us wealth" *(Atharvaveda).*

"Harness the ploughs, fit on the yokes, now that the womb of the earth is ready to sow the seeds therein" *(Rigveda).*

"I take the sickle into my hand with a prayer to thee" *(Rigveda).*

"Let the sickles cut down the heavy crop of grain" *(Rigveda).*

"As barley is harvested by separating the earheads from the stalk" *(Yajurveda).*

"Thou milkest the nutritious grain from the humid stalk" *(Rigveda).*

Cutting down crops to ensure ratooning, and pruning, are both mentioned *(Rigveda).*

Treatment of grains: The cleaning of grains and their filling into granaries are referred to *(Rigveda, Yajurveda).*

Pests and diseases: Prayers are offered for treatment against pests and diseases *(Rigveda).*

1.6 Post-Vedic Practices

Some quotations from the great *Arthasāstra* of Kautilya, written about 300 BC, are instructive.[24a] These are found in the chapter directed to the Superintendent of Agriculture.

"When one-third of the requisite quantity of rain falls both during the commencement and closing months of the rainy season, and two-thirds in the middle, then the rainfall is considered very even."

"Where rain, free from wind and unmingled with sunshine, falls so as to render three turns of ploughing possible, there the reaping of a good harvest is certain . . . Accordingly as the rainfall is more or less, the Superintendent shall sow the seeds which require either more or less water."

Seeds to be grown at the commencement of the rainy season, and then in the middle of it, are first listed. "Safflower, redgram, horsegram, barley, wheat, peas, linseed and mustard are to be sown last."

"Lands that are beaten by foam (riverbanks) are suitable for sowing gourds and the like; lands that are frequently overflown by water for long pepper, grapes and sugarcane; the vicinity of wells for vegetables and roots; low grounds for green crops; and marginal furrows between two rows of crops for fragrant plants, medicinal herbs, costus roots, yams and the like."

Dressings for various seeds to ensure successful sprouting include those of "cottonseeds (asthibija) with cowdung". Elsewhere it is asserted that "where there is smoke caused by burning the essence of cottonseeds and the slough of a snake, there snakes will not stay."

Another chapter has injunctions to the Superintendent of Forest Produce, now quoted.[34b]

He "shall collect timber and other products of forests by employing those who guard productive forests. He shall not only start productive works in forests, but also fix adequate fines and compensations to be levied from those who cause any damage to productive forests except in calamities."

Numerous trees and plants are listed. "Trees of strong timber" include mahua (*Madhuca indica*, madhuka), sal (*Shorea robusta*, asvakarna or talasarja) and yellow sal (? priyaka). The "group of fibrous plants" includes arka (*Calotropis gigantea*) and linseed (*Linum usitatissimum*, atasi). Those that "yield flowers" include the safflower (*Carthamus tinctorius*, kusumbha) and the palas (*Butea monosperma*, kimsuka). All these are oilseed-bearing materials considered in this book.

1.7 Later Agricultural Practices

Sanskrit Literature

Among later texts are some that deal specifically with agriculture and animal husbandry.[38] Varahamihira's *Brhat Samhitā* (c. 550 AD) is an early work, and the *Vishnudharmottara Mahāpurāna*, *Agnipurāna* and *Harshacharita* are all of about 500 to 700 AD. Several works are of much later date: the *Krishi-samgraha* (Manual of Agriculture) of Parasāra, of about the eleventh century AD;[39A] the *Krishi-sakti* of Kasyapa, dated somewhere between the fifth and the tenth centuries AD; the *Vryksayurveda* of Sūrapāla, recently dated at before the twelfth century AD[39A]; and the *Upavāna-vinōdana* of Sarangadhāra (ca. 1300 AD). Some quotations from these works are of interest.

"To promote inflorescence and fruiting, a mixture of one adhaka of sesame, two adhakas of goat or sheep excreta, one-fourth adhaka of barley powder and one tula of beef thrown into one drona (four adhakas) of water, and standing over for seven nights, should be poured round the roots of a plant" *(Brhat Samhitā)*.

"Oilcake is considered to be an elixir for cattle. Wet grass and cold water for drinking should be eschewed from their feed" *(Vishnudharmōttara Mahāpurāna)*.

"Cold fish water (should be used) for the mango, salt water for date and coconut palms, and vidanga, fish and flesh water for all plants" *(Agnipurāna)*. Clear knowledge of the value of manuring for field crops, as opposed to such benefits in flowering and fruiting plants, has been dated from about this time, namely, the seventh century AD.[39A]

Besides the plough, agricultural appurtenances were the "srni (sickle), khanitra (hoe), musala (pestle), ulukhala (mortar), surpa (winnowing basket), dhanyakrt (winnowing fan), calani (sieve), sthivi (granary) and methi" (the post in the threshing floor round which cattle turn) *(Krishi-samgrahā)*.[39] The ulukhala and musala will figure in considering the development of the chief oilseed processing device of India, the ghani, in Chapter 7. The winnowing basket and fan are still used in processing several oilseeds (Chapters 2 and 7), and especially the safflower. It was general to have a common threshing ground called khalya near the fields; the produce was spread out there, to be threshed by the feet of cattle hitched to a post and moving round in a circle.

"Dry seeds thoroughly in the sun; do not keep them down" *(Krishi-samgrahā)*.

"In the month of Magha, a dung heap is raised by a spade, dried in the sun and made into smaller balls. In the month of Phalguna (10 months later), these are placed in holes dug for the purpose, and afterwards scattered in the fields after sowing" *(Krishi-samgrahā)*. Manure decomposing under the earth is rich in humus, and nitrogen lost in movement is conserved.

"The cultivators may sow in due season and in regular rows the seeds *(inter alia)* of cotton, castor and mustard in fields on high land" *(Krishi-sakti)*.

"The cultivator should collect the crops of wheat, sesame, mustard and other grains on the threshing floor after having sifted them free of dust, sticks and stones using fans and winnowing, and clean them by the processes of pecana (?) and camana (?)" *(Krishi-sakti)*.

"By growing trees like sal and sandal, a king should provide material for housebuilding by his subjects.... In forest regions or their precincts, and on the tops and slopes of hills, he should grow big forests radiant with many kinds of trees" ...."On vast tracts of lands or with water enclosures", the trees to be grown included the oil-bearing "castor, neem, mahua, pilu, and undi" *(Krishi-sakti)*.

"The coconut tree always puts forth fruit quickly if watered with the cooled-down decoction prepared by boiling the seeds of masa, mudga and mura (the first two being pulses, the last a fragrant plant) in water, then grinding and mixing them with wine and salt" *(Vryksayurveda)*. Use of salt for coconut trees is a common recommendation.

"The red grape vine thrives with flower and fruit if nourished with the extract of ground sesame (palala) and fish, and manured with the excreta of cocks" *(Vryksayurveda)*.

"One should boil the flesh, fat and marrow of deer, pig, fish, sheep, goat and rhinoceros in water, and when it is properly boiled one should put the mixture in an earthen pot and add to it milk, sesame oilcake powder, pulses boiled in honey, the decoction of pulses, clarified butter and hot water...when the pot is put in a warm place for about a fortnight, the mass turns into kunapa water, which is very healthy for plants in general" *(Upavāna-vinōdāna)*. It must also have been very expensive!

"A mahua tree puts on a beautiful and dignified appearance like a being deserving of worship when it is watered with the compounds made up of the broth of the roots and leaves of kostaki, pippala (long pepper), kunapa water and powdered resin" *(Upavāna-vinōdhana)*.

Southern Proverbs

The oldest language of south India is Tamil. While the spoken language, less so the written, is of considerable antiquity, the literature that has survived is far less ancient than the Sanskrit writings that have been considered.[27c] The oldest is a fragment, a grammar called the *Tolkāppiyam*, believed to date from about the second century BC. Between the second and the fifth centuries AD a number of collections were compiled, probably at three great gatherings of poets called Sangams. These include the "Ten Idylls," the "Eight Collections" and the "Eighteen Minor Didactic Poems." There are also two major compilations. The *Puranānooru* is a compilation of the works of 1,500 poets, and the *Tirukkural* written by Tiruvalluvar is a text in three parts concerned with the three major preoccupations of living, which are dharma or duty, artha or craft, and kama or love. A selection of sayings and proverbs related to agriculture from both literature and folklore will serve to reflect the agricultural ethos of this part of India.[40]

—Low-lying ground is preferable to high ground, but proximity to a sluice even overrides that.

—New dry land, and old wet land are superior in quality.

—A land without tillage and curry without pepper are both of no avail.

—Ploughing can do what manuring cannot.

—Cattle manure for dry land, but for wet land sheep manure.

—Plants should be allowed to perish on the land on which they grow.

—Neem leaves will improve salt land.

—To remove saltiness in soil, use neem oilcake.
—Neem oilcake is a valuable manure.
—A good well is paved around with stones, and a good field has bunds to protect it.
—Sink a well after noting the location of anthills.
—Crops not weeded are one-fourth of a crop.
—Manure the fields till the crop begins to ear, and weed it till the ears have ripened.
—Well-dried seeds will keep without harm.
—Even if the seed is good, it should be dry.
—Husks protect the seeds from harm.
—A sapling not protected by a fence, and an oilmonger who does not use an oil press, are both in the wrong.

1.8 Current Practices Related to Oil-bearing Materials

Agricultural practices have persisted through the centuries, largely unaffected by whether the rulers were Hindu kings, Moghul emperors or British administrators. The following excerpts from a modern text entitled *Principles of Crop Husbandry in India*[40] that relate to oilseed-bearing materials show how traditional practices still dominate a great deal of Indian agriculture.

Green manures, though reputed to 'eat up' alkaline soil, probably act by improving physical condition, that is by improving drainage. Most green manures are useful in this way but the leaves of *Calotropis gigantea* (akra) and neem are considered specially beneficial.

Karanja and neem leaves are believed to keep insects and larvae from the soil and thus eliminate crop pests. Even regular plantations of karanja are maintained by landholders, since in some places rice will simply not be cultivated without the use of large quantities of karanja leaves.

Oilcakes are quick-acting manures; their effect can be seen in the strikingly deeper green colour of leaves within a week of application. Oilcakes differ in their rate of nitrification in the soil. Castor oilcake acts better than others at the same nitrogen level. To ensure uniformity, one method of application is to mix the oilcake mash with the irrigation water. Oilcakes as a rule are not used at sowing time, but only after the crops have made a certain degree of growth, when the root system has developed and is able to use the fertiliser. Ghani oilcakes are preferred, since the oil in them prevents quick nitrification in the soil, and the oilcake is believed to have a more lasting effect.

Modern Indian agriculture of oilseeds runs the gamut from the most traditional to the very sophisticated, and will not be further elaborated in this book.

CHAPTER 2

Marketing and Trade

2.1 Development of Trading and Guilds

Indus Valley Cities

The comfortable civilisation of the Indus Valley must have had a well-organised commercial basis.[42a] Grain, as we have seen, came by river and was stored on a huge scale probably for public distribution in Harappa, Mohenjodaro and Lothal. Trade was carried on with the village cultures of Baluchistan on the one hand, and with many other parts of India on the other, which returned woods of various kinds, conch shells, copper and jade. Trading with the Sumer civilisation of Iraq brought silver, turquoise and lapis lazuli, and carried from the Indus Valley a variety of goods, including sesame and linseed oils (page 7). An excellent system of weights and measures (see page 22) was in use. Definite evidence was found of large workshops employing several craftsmen under the same roof, suggesting some form of corporate trade.[9d] The evidence of multiple sealings on traded goods also suggests partnership in trade.[9d]

Vedic Phase

Early Vedic stages: The Vedic Aryans, unlike their urban Harappan forerunners, were a pastoral people, and the economy was one of village communities of agriculturists and cattle owners. The Vedas describe the fights of the newcomers with the panis. This is a word which may have originated from pan, trade or barter,[43a] and would mean that the panis were wealthy traders who refused to patronise the Vedic priests, thus earning their jealousy.[33] Specific artisans in Aryan society were wood workers, basket makers, rope makers, weavers, dyers, potters, tanners, goldsmiths, metal workers, physicians and corn grinders.[42b] In this phase, the trader or merchant was rather a despised figure, "of no interest to his betters except as a source of profit."[42c] By the time of the Code of Manu, certain professions were later allowed to an Aryan, but others were taboo, such as the sale of condiments, sesamum stores, salt and cattle.[44d] The unit of barter was the unwieldy cow, or rice, or gold jewellery.[42d] There is

a faint reference to some form of group organisation implied in the word sreshthin : by the end of the Vedic period this certainly meant a headman.[43a]

Buddhist period: By Buddhist times, after 500 BC, the guild or sreni system was well-established. Source-material from these times are the 547 Jātaka tales (Section 1.5), which are often didactic in nature. The two great divisions of the Buddhist Pali scriptures have frequent references to "the 18 guilds," though an actual count of all those mentioned yields about 30.[43a] This includes oil-millers (*tila-pishākas),* and even a guild of thieves![42e] The figure 18 seems to have been an early convention, but it persists even in an inscription of the seventeenth century AD.

In the Jātaka stories, a clear difference is made between two sorts of guilds. Hereditary trading or merchant families founded corporations headed by an alderman or jetthaka, and were obviously groups of some substance. Thus the Jātaka tale of *The Converted Miser* refers to Illisa, a guild-master of Varanasi, who was worth Rs. 800 million.[45] Groups of artisans formed guilds, also headed by a jetthaka; these were hereditary professionals, who lived on particular streets or quarters of the town (as they still do) (Fig. 3) or even in whole villages.[43a] Another type of professional group consisted of rich money-lenders or bankers, called sreshthin or sethi, a word which survives to this day in names like Setty, Chetty and Seth. The guilds of craftsmen were similar to those of Europe in the Middle Ages.

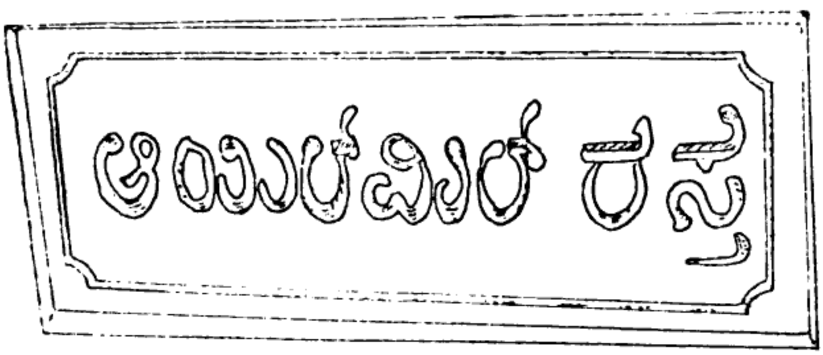

Fig. 3. "Oilmill raste" or oil mill road, in Mysore city (Source: K.T. Achaya)

Small villages were the rule. Lamenting the death of Buddha in a small town like Kusinagara, the disciple Ananda mentions six towns only as being really fit for him to die in.[42f] As regards daily trade, foodstuffs for the towns could only be brought to the gates, while bazaars and workshops generally occupied their own special areas. These took the form of small shops raised slightly above street level, with the owner squatting in front.[46a] Principal tradesman, in town or village alike, were the milkman, spice vendor, oil-monger, perfumer and tavern keeper.[46a] Greengrocery was sold at the four town gates. Slaughter houses were located outside the city walls, and flesh was sold at the cross-roads outside big cities.[32] Retail

shops carried goods like textile fabrics, dry groceries, perfumes, flowers, gold and jewellery, and vegetable oil.[32] Money (the kahapana, a square coin) was well-established, and it was left to a producer or dealer to prevail by competition through free exchange, without price fixation or regulation.[33] The great trade routes ran from north to south-west, north to south-east and east to west, by road and water, using caravan and ferry. Of course only expensive goods could bear the cost of such long transport.[33] Daily needs were met by local produce, each village being its own cosmos.

Mauryan Era

By 300 BC, when the *Arthasāstra* of Kautilya was written, guilds were a force to reckon with. Several organisational forms of guilds had developed, the sreni, naigama, gana, and puga, though the definitions of these are disputed.[47] Srenis were definitely all of one occupation, manufacturing a single item of merchandise, but their members could be of the same or different jati (an early word that developed into caste). Naigama were essentially groups who travelled for trade purposes. Gana had come to have the connotation of an assembly of armed persons, while puga were those bonded together for strength towards a common purpose, either through practising a common trade, or through living in a common locality, or the like. In respect of their legal authority, Kautilya states that violations of any member should be visited by a fine, while the *Gautama Dharma Sūtra* reveals that the srenis were empowered to make laws for themselves.[43b] The headman played an important role in civic affairs, and could represent his organisation at court. The Superintendent of Accounts had to regularly enter, in special registers, the history of the conventions, customs, wages and transactions of each corporation. To receive deposits from the guilds (these could be taken back in times of distress), three trustworthy commissioners were appointed. Taxes paid by the guilds were an important source of revenue, and guilds were allotted offices in the city. Soldiers maintained by the guilds were listed in the *Arthasāstra* as those whom the king should call upon for offence or defence, while the guilds themselves were liable to be used by him both for political purposes and for money. In fact the guilds functioned like modern banks, stable bodies that received deposits of public money and paid interest on them, and who owned corporate property and laid down articles of association. Epigraphic evidence (see Section 2.2) shows that guilds were frequently entrusted by people with administering perpetual endowments, and that they themselves also made handsome donations for just purposes. To give one example, in 437 AD, a magnificent temple of the sun was raised by the silk weavers' guild at Mandasor, which was again repaired by the same guild 36 years later. A long inscription recording these services also sets out the many activities and high ideals of this guild.[42g]

Trade and Guilds in South India

In south India, village administration appeared to have rested with learned Brahmins called mahājanas. They make their first appearance in inscriptions of the sixth century AD,[48] and are frequently mentioned for many centuries thereafter. In towns, where mercantile interests were uppermost, a guild system prevailed. This was perhaps influenced by those of the north, being likewise of two types,[49] merchant guilds and craft guilds. In time the former grew powerful enough to perform social and religious functions, regulate economic life, impose taxes, own banks, and have not just their own insignia, banners, umbrellas and fly-whisks (chowris), but even their own militia (one inscription mentions 1,000 warriors).[50] The town administration was predominantly mercantile; while there were a few civic functionaries, guilds like those of the oilmen, spinners, weavers, and so on were heavily represented. These guilds were very large: one inscription refers to four headmen representing the guilds of 360 cities,[43c] another to an organisation of 505 merchants,[51] and yet another, found in Sumatra (Indonesia), to "the five hundred of the 1,000 quarters."[47]

Even entry into a powerful guild of south India, like the Manigraman, Anjuvanam or Viravalanjiyar (Company of Worthy Merchants) was a momentous event. In one inscription a merchant, Iravikkovan, when admitted to the Manigraman, was given lordship over the oil-mongers and five classes of artisans, and the sources of income available to him as lord of the city were enumerated; further, the elevation was not just personal, but hereditary and perpetual.[52] Another mercantile federation even chose a diamond as the symbol of its guild.[53] Being rich and powerful, eventually these guilds themselves lost interest simply in trading, seeking instead to protect, further and regulate the activities of their merchant members.

Several inscriptions mention the "500 svamis of Ayyavole". This body had members in every important city in south India and was controlled by a central council at the city (now called Aihole) from which the group drew its name.[42e] The original number of mahājanas or svamis in the town may have been 500, after which the appellation simply carries by rote down the centuries. Frequently even the name of a place is followed by a numeral, thus Aije-300 or Vengi-1,000, the number rising even to 99,000. Many explanations have been suggested for this number: that it is the number of villages, the number of estates, or the tax income in coins. An attractive theory is that the number denotes the units of land, varying in area from 0.5 to 4 ha, into which a region was divided for tax purposes, which were always meticulously recorded.[54] Since these surveys were also subject to reassessment and change, Vengi could occur at different periods with the numbers 1,000, 12,000, 13,000 and 16,000 after it.

2.2 Epigraphic Records of Guild Activity

Nature of Inscriptions

The pictographic writing on Indus Valley seals, the earliest epigraphic records of India, still remains to be deciphered. Thereafter, while literary works like the Vedas, Brāhmanas and Upanishads continue to be transmitted orally, writing languished. It is only in Buddhist times that inscriptions in the Brahmi script begin to appear on sacred relics, and in stupas.[55] The great Emperor Ashoka proclaimed his ideals of tolerance, charity, tree-growing, hospices and the like by inscriptions cut on smoothened stone faces through the length and breadth of India, using dialectal spoken forms of Sanskrit called Prakrit, and homely local words and turns of speech. In later times inscriptions were either made on metal (usually copper plates) held together with a metallic ring, or on stones slabs in or near temples. First Prakrit, and later Sanskrit, were the usual languages employed for a very long time all over north India. In south India other languages came to be used as they developed: Tamil from about the third century AD, Kannada from about the sixth and Telugu a century or so later, with Malayalam following from about the tenth century AD.[56] The numbers of these inscriptions, constantly being brought to light and transcribed, are enormous. Thus in the Kannada language alone there are an estimated 30,000 epigraphs, of which some two-thirds have been edited and published.[57] Many contain records of donations made, by royalty or others, to monasteries and temples. Some that are relevant to oilseeds and guilds will now be described.

Actual Epigraphs

Two copper plates from Valabhi, Bhavnagar (Gujarat) dated 272 of the Saka era, which corresponds to 350 AD, record grants to the mendicant Buddhist priests: these include "oil for lamps" in the first, and "oil for the lamps of the sacred Buddhas" in the second.[58]

Three copper plate inscriptions from Kalvan village, Nashik district (Maharashtra) record grants by a chief of a ruling Ganga family "to the illustrious Muni Surratadeva in the Jain temple."[59] These grants include several pieces of land, two oil-mills (taila-ghānakas), 14 tradesmen's shops and 14 coins (drammas), all of which are meant to defray the expenses of worship, which are enumerated in detail.

A Buddhist cave inscription at Junnar, written in Prakrit, records the grant to the guild (sreni) at Konachika by a lay worshipper, Aduthuma, of the income from a field for planting karanja trees, and from another field for planting banyan trees.[60a] These trees were probably meant for the benefaction of the public.

Another Buddhist cave inscription at Nashik, dated about 200 AD, is a fragment in a mixed dialect, through which the female lay worshipper, Vishnudata, daughter of Agnivarman, wife of Rehbila, mother of Visvavarma, records an endowment of money derived from funds that she has

invested with three guilds of artisans: potters, fabricators of hydraulic machines (odayayantrika) and oil-millers (tilapishaka).[60b] Such genaeological details, when furnished for rulers, have helped to date Indian dynasties accurately.

Written in the Sanskrit language, but using Telugu characters, the plates of King Choda Annadeva now in the museum at Rajamahendravaram record, *inter alia*, the gift by the King of an agrahara or village to the mahājanas (Brahmins).[61] Such mahājanas often figure as administrators of village affairs, one inscription describing at great length their virtues, which included impartiality to all religious sects.[62]

The Lahadapura inscription of the Gazipur district of Uttar Pradesh, inscribed in 1173 AD by Jayachandra (Plate 1), is a private document, which is rather rare; it is doubly rare in that it records an activity typical of mahājanas in the south, but uncommon in the north, namely the actions taken by the assembled brahmins (dvijas) to guard against robbers in the neighbourhood.[63]

Finally, two copperplate inscriptions formed in the Vaillabhattasvami temple at Gwalior (Madhya Pradesh) show donations made in 923 and 933 AD by the inhabitants of the town to the temple.[64] The second of these inscriptions is of 23 lines, among which are the following: "And in this same year, on the ninth day of the dark half of Phalguna, the townspeople gave to the two above-mentioned temples a perpetual endowment to the effect that, in order to provide oil for the lamps, the chiefs of the oil-millers who dwell in Sri-sarvysvarapura, namely Sarvasvaka the son of Bhockhchaka, Jayasakti the son of Madhava, Sahulla the son of Sivahari, and Gaggika the son of Sanghaka; the chiefs of the oil-millers who live in Srivatsasvamipura, namely Singhaka the son of Kundaka, and Khohataka the son of Valluka; the chiefs of the oil-millers who dwell in Chachchikahattika and Nimbadityahattika, namely Jajjata the son of Deuvakka, Goggaka the son of Vachchillaka, Jambaka the son of Dedduka, and Jambahari the son of Rudrata, and the other members of the entire guild of oil-millers should give one palika of oil for each oil mill on the ninth day of the bright half of every month".

Two plays of Kalidasa, the great playwright who lived about the fifth century AD, namely *Raghuvamsa* and *Sakuntala*, mention a famous guild of oil-men who lived in Indrapura (today's Indore in Madhya Pradesh) during the time of the ruler Skandagupta (455 to 467 AD).[65] They are noticed as producing ingudi oil (from the seeds of *Balanites aegyptiaca*) for lighting lamps, curing boils and dressing the hair.

2.3 Taxes, Weights and Measures

Taxes

In the Vedic concept, all land and water was the property of the king, and the bhaga tax on agricultural fields, herds and flocks was his due. This was usually a quarter of production, but ranged from a sixth to a

third, and was paid first in kind, and later in history in cash.[46b] On cattle, the tax was eight 'measures' of ghee, or later one pana, a head. In addition, there was an annual tax on water use, and on state services such as land surveying, land demarcation, pasturage and irrigation, besides a collective tax on the village as a whole. Village headman levied taxes on daily necessities that were delivered to the door, such as flowers, fruit, vegetables and grass.[46c] Craftsmen, like merchants, were subject to heavy taxes and duties, there being a tax on the shop premises, on the scales, on weights and measures, on the implements used, and finally on the produce itself; these were payable in kind or money.[46a] Octroi was collected at the gates of the city on all items, imported or exported. About 300 BC, imported commodities paid one-fifth their value, and the rate was one-tenth to one-fifteenth for various textiles of linen, cotton, silk and wool, and for carpets and curtains.[34a] A lesser rate of one-twentieth to one twenty-fifth prevailed on threads, cotton, scents, medicines, and fibres on the one hand, and on food materials like grams, sugar, salt, liquor, cooked rice, vegetable oils and the like on the other.[34b] These were in general collected by the town assemblies, constituting the municipal administration, on behalf of the king. For temple upkeep, as seen, taxes in kind could be diverted from those paid by merchants dealing in oil, betel leaves, coconuts, sugar or flowers.

Weights and Measures

Excavations at Mohenjodaro,[6] Lothal[9e] and Kalibangan furnished a beautiful series of stone weights. The Lothal weights are in two series. The cubical weights are in the ratio 1, 2, 4, 6, 8, 16, 32, 64 and 120, which was the Indus Valley standard, while the spheroid ones are in the ratio 1, 7/2, 7, 14 and 28, conforming to the Heavy Assyrian Shekel prevalent in the Mesapotamian valley at the time.[9e] The small weights were in the decimal system, and the large in the binary. From the vast number found at Mohenjodaro, the unit weight was calculated to be 0.8565g.[6a]

An interesting series of weights and measures are set out in the *Arthasāstra* of 300 BC and the *Mânava Dharma Sutra* (The Code of Manu) of about 100 BC, which run somewhat as follows:[34c]

Natural weights			*Silver weights*		
1 pepper seed (likya)	=	1 black mustard seed	2 ratis	=	1 masha
3 black mustard seeds	=	1 white mustard seed	16 mashas	=	1 dharana
6 white mustard seeds	=	1 medium barley corn (yava)	10 dharanas	=	1 satamana
3 barley corns	=	1 krsnala or rati			

Copper weights

80 ratis	=	1 karsapana

Diamond weights

20 rice grains	=	1 dharana

Gold weights

5 ratis	=	1 masha
16 mashas	=	1 suvarna
4 suvarnas	=	1 pala
10 palas	=	1 dharana
10 dharanas	=	1 tola
100 dharanas	=	1 ayamana, or measure of royal income

The king's balance was called the ayamani. The public balance, servants' balance and harem balance showed weights successively decreasing by 5 per cent, to 95, 90 and 85 per cent of that shown on the ayamani. The difference constituted state earnings on every transaction.

In later years, the rati held its pride of place as the basic unit of measurement. This is the beautiful seed of *Abrus precatorius*, shiny and red, with a circular black patch at one end. It is still used for weighing by goldsmiths and diamond merchants in their tiny brass pan balances. As the centuries went by, the system evolved in the following direction:

8	ratis	=	1 masha
12	mashas	=	1 tola
80	tolas	=	1 ser or seer
40	seers	=	1 man or maund

Even in the forties, each of these weights, the tola, ser and maund, had different connotations in each region in the country, but were eventually standardised as follows for trade purposes:

1	tola	=	11.66 grams
1	seer	=	0.933 kg
1	maund	=	37.32 kg

Thus the basic rati would have a weight of 0.121 gram.

Volume measures in later Vedic time ran as follows:[34c]

4 kudumbas	=	1 prastha
4 prasthas	=	1 adhaka
4 adhakas	=	1 drona
20 dronas	=	1 kumbha
10 kumbhas	=	1 vaha

There is difficulty fixing the absolute volumes, but a prastha appears to have been about 600 ml and a drona nearly 10 litres. Those who traded in ghee, according to the *Arthasāstra*, should give the purchaser one thirty-secondth part more as taptavyaji, which was "compensation for

quantity owing to its liquid condition," a clear reference to specific gravity. For oil, the excess was one sixty-fourth. While selling all liquids, traders were expected to give one-fiftieth more as manasrava, to compensate for adhesion to the measuring can. While 21 prasthas made up a waraka of ghee, a waraka of oil was only 16 prasthas; however one-fourth of a waraka, whether of ghee or of oil, was called a ghatika.

Balances for heavy public weighing, with a centrally-suspended balance arm and two end-pans, appeared about the sixth century BC, and are still used.[46a] For long before that scales called tula were used. These consisted of a single pan suspended by a short chain from one end of a graduated arm, and counterpoised with a sliding ring moving along the graduated longer arm; or else the object was removed and weights added till a counterpoise was restored. Payment was made by cowrie shells or barter before copper coins became common in Buddhist times, by way of copper mashas and karsapanas weighing about 0.047 and 0.75 gm respectively.

One of the duties sternly enjoined on the king was a careful regulation of weights and measures, which were checked every four months and certified.[46a] In the *Mahābhārata* (ca. 400 BC), the sage Narada asks King Yudhisthira: "Are the four items of varta (agriculture, trade, cattle-rearing and money-lending) carried on in your kingdom by honest men, since on these depend the happiness of your subjects?"[44b] Kasyapa, writing somewhere in the fifth to the tenth centuries AD, says that the duties of a king were to have produce collected and stocked in markets at the cross-roads, and to "appoint rich vaisyans (hereditary traders) who were well-versed in trade for the sale and purchase of these commodities," furnishing them with "measures made from iron sheets or boards of hard wood," and having "the rates of buying and selling food-grains etc. announced in all parts of the country."[38a] Among the foods listed are sesame, mustard oil and "foods produced by oilmen," meaning perhaps oilcakes.

2.4 Foreign Trade

Early Times

The Old Testament records how in the time of King Solomon, about 1000 BC, the ships of Tharshish brought gold and silver, ivory, apes and peacocks from India. Here the Hebrew words used, like koph for monkey (Sanskrit *kapi*) and tukki for peacock (Tamil *togai*) were of Indian origin.[42h] Even a millennium before this the Indus Valley civilisations, as seen, had sea trade exchanges with the Middle East. A merchant's house at Lothal yielded pottery, and nine gold pendants strung on an axial tube, both derived from Sumer,[9d] besides several Harappan seal chert blades and carnelian beads, the latter being a commodity made in Lothal and much in demand for export. The succeeding Vedic society was more stay-at-home, but in Buddhist times, the Jātaka tales are full

of stories of ships heading for places like Baveru (Babylon) or the Golden Land, of vessels carrying 500 and 700 passengers, and of shipwrecks.[32] The Emperor Ashoka about 250 BC sent his son and daughter to Sri Lanka to preach Buddhism. Chinese literary records refer to maritime trade activity with India from Buddhist times. Kautilya refers to a Board of Admiralty and Naval Department.[43d]

Among the items of trade to Sumer were sesame (se-gis-i) and linseed (i-gis) oils, and perhaps even their seeds.[79] On the eastern seaboard, as late as the sixteenth century AD, the coast near Orissa was termed the gingelli coast (the south Indian word for sesame) because of the plentiful supplies of this oil for internal and external trade.[66a] Ghee (clarified butter fat) was also exported: from Bengal, wrote John Fryer about 1680,[66a] butter "is in such plenty that although it be a bulky article to export, yet it is sent by sea to numberless places." This was true even at the start of the Christian era when ghee was among the articles that went to the Holy Roman Empire from India.

South India

The Italian historian Strabo recorded in 19 AD "that about 120 ships sail from the port of Myos-Hermos (on the Red Sea) to India."[67] He also described how an Indian sailor was found drifting in the Red Sea in a boat: taken to Egypt, he offered to show the Egyptians and Romans there the sea route to India, which of course had historically been known to Indian seafarers.[68] The monsoon winds which blow across the Indian Ocean in both directions at regular seasons were discovered in 45 AD by Hippalos, a Greek sailor, and a brisk trade between south India and the Roman Empire thereupon ensued. Hordes of Roman coins have been found in several places in India which cover the reigns of Augustus, Nero and Caracalla during the first 250 years of the Christian era.[69]

About the middle of the first century AD, an unknown Greek sailor based in Alexandria visited India, and set down, in his *Periplus Maris Erythraei*, the ports and trade of the south[68] (Fig. 4). The Indian coast was dotted with harbours, in which the ships of many nations, both to the east and the west of India, carried on a brisk trade. According to the *Periplus* there were small coasting boats for local traffic, larger and more complex craft of greater carrying capacity, and big ocean vessels going to Malaya, Sumatra and the Ganges ports. These ocean-going vessels were larger, and far greater in number, than the Egyptian ships.[70] Some 50 years later, Ptolemy lists 11 ports on the eastern coast and another 30 walled towns.[20] In a famous passage, Pliny lamented the drain of currency from the Roman empire to India to the tune of 100 million sesterces every year, "so dearly do we pay for our luxury and our women."[42h]

Corroboration is forthcoming from the Tamil literature of the same period, which describes Yavanas (Greeks) of harsh speech, who had their use as guards for the king's place. Roman amphorae with two handles, in which cool wine was imported for the use of south Indian kings, have

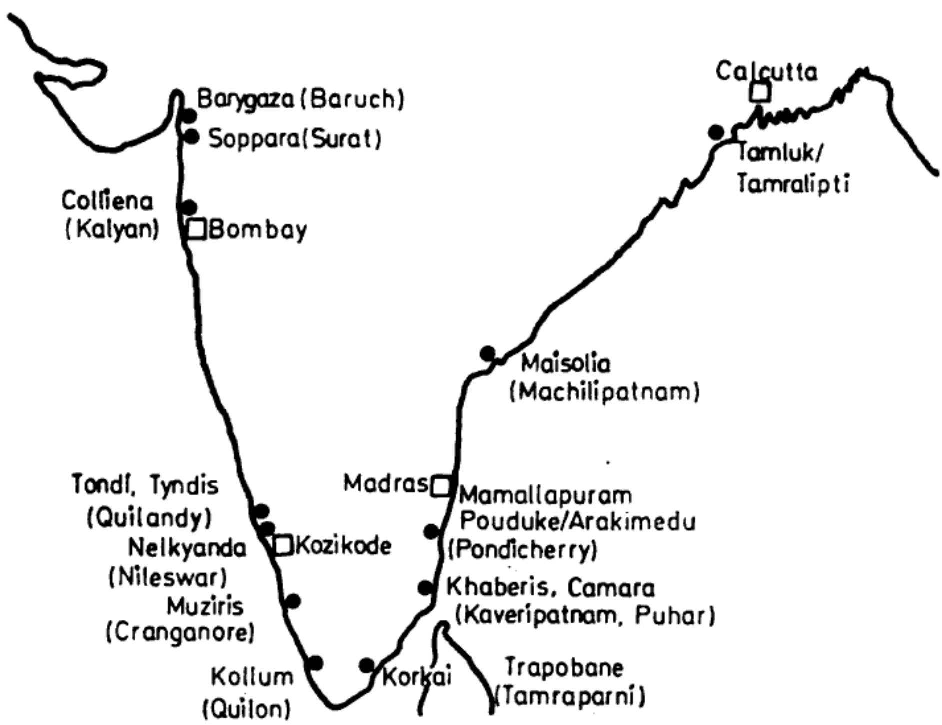

Fig. 4. Ports of south India during the 1st and 2nd centuries AD mentioned by Greek writers

been found in numbers in a Roman warehouse at Arikamedu, a port just outside Pondicherry.[71] A vivid pen portrait of the city of Madurai written at about this time by Mankudi Maruthanar in his *Mathuraikanchi* conveys the excitement of the market place: "Sacks of pepper and of the sixteen kinds of grains such as paddy, millet, gram, peas and sesame seeds are heaped in the grain-merchants street; the brokers move to and fro with steelyards and measures in their hands, weighing and measuring the pepper and grains purchased by the people . . . . The hotels and restaurants are now, in the cool of the evening, crowded with visitors who feast upon luscious fruits such as the jack, mango and plantain, and on sugar candies, tender greens, edible yams, sweetened rice and savoury preparations of meat."[67]

The colonisation of large parts of South-East Asia in the first few centuries of the Christian era by seafarers from eastern and southern India brought in its wake Hindu kingdoms in Sri Lanka, Burma, Thailand, Cambodia and Indonesia that flourished right down to the fifteenth century AD. These intrepid people went even further. An epigraph dated 923 AD has been found in Tihosuco in the Yucatan province of Mexico recording the visit there of a merchant ship captained by one Vusaluna "thoroughly exploring the coastline."[72] Gradually however Arab and later Portuguese traders took over the foreign trade of India.

The persecuted from many lands fled to make their homes in India. St. Thomas the Apostle is believed to have founded the Syrian Christian

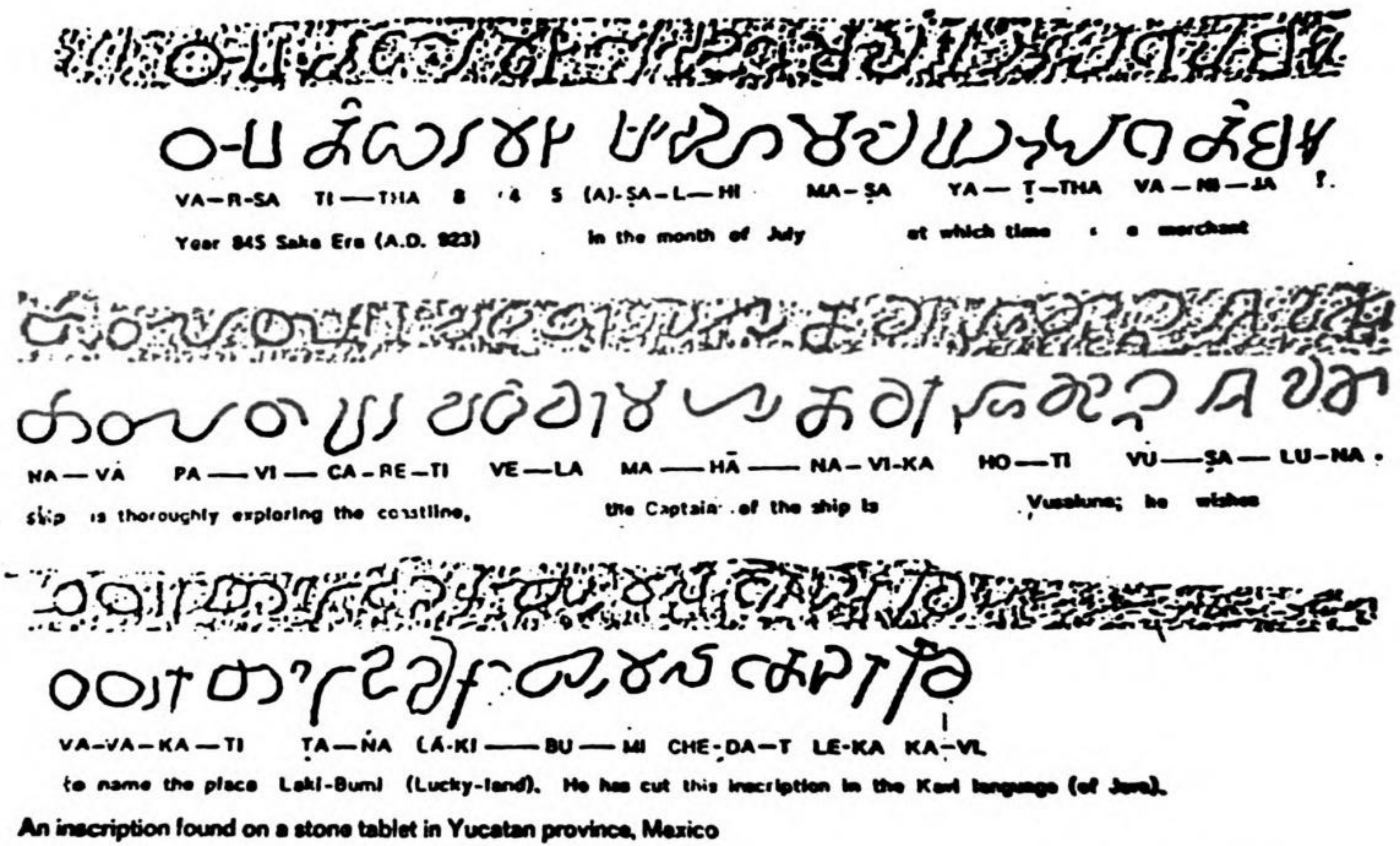

Fig. 5. Inscription of the 10th cent. AD from Mexico, recording the visit of a ship manned by an Indian captain
(Source: The Hindu, Madras[72])

church in Kerala in 52 AD, baptising 40 families and later being martyred near Madras on a hillock still called St. Thomas Mount.[73] After the destruction of their temple in Jerusalem in 68 AD, the Jews fled to India and settled near Cochin in Kerala. Their synagogue and quarter still survive, though sadly depleted in numbers in the last three decades. Copper plates written in the ancient Tamil of the second century are still believed to be in their possession.[67] In the early eighth century AD, Muslim religious persecution in Iran drove the followers of Zarathustra from their home to the west coast of India; they were hospitably received by Prince Yadav Rana, and made their first settlements at Diu in Saurashtra (Gujarat) and at Thana, near Bombay, going on to become the diligent Parsis of India.[42l]

2.5 Marketing of Oilseeds in Recent Times

Accurate and detailed accounts written during the decade 1940 to 1950 describe the trade in oilseeds in India. These serve to show the marketing practices in vogue when India was in the last stages of being a colonial country, moving towards its independence. Four such accounts will now be summarised, each having an identity of its own. Linseed is a well-established crop of long standing, pressed from only a single seed species. Rapeseed-mustard is a historical crop of north India, raised in several varieties, and still handled in largely traditional ways. The coconut is very much a crop of south India, with unique steps in its transport, handling and drying. Groundnut has become, in less than four decades, India's largest oilseed crop; the need for a major decortication step influences its marketing system.

Marketing of Linseed (1939)[74]

Supply: Linseed in the years between 1934 and 1937 was produced (as percentages) in the United Provinces 30.9, Central Bihar 18.1, Central Provinces and Berar 17.9, Central Indian states 10.2, Hyderabad 7.9 and other areas 15.0. Because of the practice of mixed sowing, these proportions could be slightly uncertain. There were two seed types, Small Brown and Bold Brown, the former with about 135 seeds to the gram, and the latter with 200. Refractions were as high as 5.5 to 6.5 per cent. Exports of linseed and its oil and cake gave India a 16 per cent share in the world trade in this commodity, Argentina being dominant.

Utilisation and demand: Lacking a large native industrial outlet, India only absorbed one-third of all the linseed oil produced. This was used as an edible oil in the Central Provinces and Central Indian states, or elsewhere in north India for the adulteration of rape-mustard oil. The major producing states retained variable proportions (Central Provinces 75 per cent, United Provinces 50 per cent, Bihar 25 per cent) of their produce for local consumption and crushing, sending the rest to Bengal or to Bombay, whichever was closer, for crushing or export.

Wholesale prices: Bold seed fetched a 1.5 to 2.5 per cent premium in price over small. In the London market, Indian linseed was preferred to Argentinian for its higher oil content and lesser price after refractions were allowed for. Indian price was dictated by the ruling price of the dominant groundnut oil, and the season, being low in February to April and October and November, and at a peak in September and December. Trading in futures occurred only in Bombay and Calcutta ports for two forward months, May and September, future prices being in close sympathy with the ready prices at both ports.

Preparation for the market: Linseed not being grown as a fibre crop in India, the entire plant was uprooted or cut down, spread on a beaten-down patch of land in the fields or near the home, and trodden on by bullocks driven round and round as the mass was constantly raked, an age-old procedure. Winnowing was done in the open by pouring the threshed seeds from a basket held at a height, after which the heavier heap of seed was collected. Since deductions were made at a flat rate, there was no incentive to improve quality.

Assembling: About 20 per cent of all linseed was brought to the market by cultivators, another 40 per cent by village merchants, money-lenders and landlords, and yet another 35 per cent by itinerant merchants who wandered from village to village. The remaining 5 per cent came through wholesale merchants and oil mills. So high were market charges in the United Provinces (some 6.7 per cent) that cultivators hesitated to bring their own seed for sale. The small primary markets were generally held weekly in villages, and were called hat or painth in north India, and shandy or santhe in the south. These played only a small part in linseed disposal, though important for certain other grains. The secondary daily markets, called mandi or ganj, were the chief assembling centres, from where linseed moved into the local oil mill trade and for export. At the tertiary or terminal markets, Bombay and Calcutta, spot or futures trading in the seed was conducted.

On arrival at a mandi, the linseed was taken to the shop of an arhatiya or aditya, a commission agent. These agents were usually armed with advances taken from banks amounting to 75 per cent of the produce value, or they could have other sources of finance. Buyers would arrive, inspect the produce, and either directly or through their broker (dalal), make bids either openly, or in auction, or under cover of a cloth by a convention of finger pressure exerted by both parties. This is an ancient system, observed by Varthema even in 1507 in south India.

The various market charges will be listed later under groundnut marketing.

Grading and standardisation: Samples were drawn on a random basis with sharp pointed probes (Plate 2) called parkhi and boma, and impurities were separated for analysis by women skilled in the task; seed size was determined using a sieve fitted with brushes rotated with a handle. Seed size, non-oleaginous impurities, oleaginous impurities and damaged grains,

and dirt and dust were the main criteria of quality, with graded allowances made for shortfalls from standards. Women were trained for such sorting.

Storage: Cultivators quickly disposed of their produce, retaining only sowing stocks for the next season. These were stored in earthen jars or pots called kothis, or in covered wicker baskets plastered with mud and with the lids always tightly sealed with mud. Bulk storage, whether in the home or on the floors of market godowns, was either in bags, or simply heaped loose. Linseed is not susceptible to weevil attack but is highly prone to damage by water and rats. If well kept, it stores without deterioration for even a year.

Handling and transport: Frequently linseed was sold even while on the threshing floor. Anything left was carried to market as headloads, in carts, on pack animals, or in lorries or by rail (which cost only 60 per cent of road transport). Water transport was even cheaper, but slow. The supplies of linseed reached the assembling market through the agency of smaller commission agents (kachcha arhatiyas), but disposal thereafter was by bigger commission agents (pucca arhatiyas) and wholesale merchants. Buyers of this seed were either exporters, or power-driven oil mills (ghanis got their supplies, about one-third of the total seed, from village merchants and landlords). Finance was mainly in the hands either of the pucca arhatiya himself, who advanced money to the smaller arhatiya to buy on his behalf, or on behalf of indigenous bankers, known as shroffs. In the terminal port markets, four oilseed merchant associations, all non-profit-sharing organisations, totally controlled the trade.

Weights and measures were highly variable, even within a single village, and even when the weight had the same name. A kachcha seer could be anything from 31 to 112 standard tolas reckoned on the standard scale of 5 tolas=1 chattank, 16 chattanks=1 seer, and 40 seers=1 maund=82.27 lbs (or 37.32 kg). A volume measure, the paili, could contain anywhere from 40 to 160 tolas. A basket measure in Assam could hold between 2 and 5 seers. Both the imperial gallon (=9-1/4 lb of linseed oil) and the Old Measure gallon (=8 lb) were in use. Only in Bombay Presidency was a systematic Weights and Measures Act in force.

MARKETING OF RAPE-MUSTARD (1949)[75]

Seed supply and use: Average production of rape-mustard seeds during the five-year period 1934 to 1939 was 1,028 thousand tonnes, of which 45 per cent was from the United Provinces. Seed was marketed as the predominant component, for example rai, with sarson, toria and taramira in small proportions (Section 3.1, p. 51). Rai was then classified as *Brassica juncea* (now *B. juncea* subsp. *juncea*), sarson was *B. campestris* var. *toria* (now *B. napus* var. *napus*) and *taramira* was, and is, *Eruca sativa*. Toria came in during December and January, and sarson and rai in the three months that followed. Hence market arrivals covered a full six-month period. Some 925,000 tonnes were crushed annually, and another 68,000

tonnes was estimated to be used thus: sowing 16,000 tonnes, condiments and pickles 37,000 tonnes, seed as direct cattlefeed 10,000 tonnes (in the United Provinces and Punjab), and as power and paste for body cleaning 5,000 tonnes. Large quantities of seeds left the United Provinces and Punjab because of demand elsewhere for crushing, mainly in Bengal, Bihar and Sind (now in Pakistan).

Prices: Sarson, with its high oil content, fetched a better price than either rai or toria, and yellow sarson was more costly than brown sarson. The different between rai and toria was very slight, and taramira was the cheapest seed of all. Bigger seeds fetched higher prices. Peak prices occurred in December and January, a deep trough in March and April, a lesser peak in June and July, and a shallow trough in September and November.

Harvesting was accomplished before the seed had fully ripened, to circumvent the problem of pod shattering. The entire plant was pulled out, or cut near the base with sickles. Linseed growing alongside could become admixed during harvesting. The sheaves were dried for four to 10 days (usually about March and April) for sarson and rai. Taramira was dried unsheaved in December, when it is cooler. Threshing, as for linseed, was by trampling underfoot by bullocks, and winnowing was done as usual from a height.

Assembling, marketing and transport: The pattern was similar to that described for linseed, which grows in much the same areas. The proportion of the crop taken to market by the producer varied: 30 per cent in the United Provinces and the Central Provinces, 50 per cent in Hyderabad state and 70 per cent in Punjab. The rest was sold at the village itself. Practices of transport of rape-mustard both on the farm and in the market, and transport by headload, carts, trucks, rail wagons and river boats, were all very similar to those described for linseed. Careful estimates showed that the farmer received 60 to 70 per cent of the price eventually paid by the consumer.

Quality and grading: Grading by name was very widely practised. Sarson-gajjar (carrot) or galbalia meant mixed sarson of all three colours (yellow, brown and red) in the United Provinces, where sarson itself went by many traditional names like tora, lotani, pirwa, rana and banga. For mixtures with linseed, the terms sarson-maghra and barra were used: such mixing was traditionally not considered unusual or wrong, and shops even proclaimed that they sold mixed oils. Using the seed colour as a prefix was common: pila (yellow), lal (red), kali (black). In Bengal, the term meghi was used for early-maturing varieties, and rai for late-maturing ones. In the United Provinces a brown toria was called maghi-lahia because it was harvested in the month of magh (January and February). In addition to such local varieties, in the United Provinces local place names were used: Cawnpore (=Kanpur) or Pukhrayan yellow, Chandausi yellow, and Lotni. Punjab had its Bold Brown Punjab and Bold Yellow Punjab, both sarson types, and also Punjab toria; this was distinguished in the trade from

Sind toria which had a higher refraction of 10 per cent. The Central Provinces had Saugor Red rapeseed (toria), Katori Red rapeseed and Dhamtari Red as recognised varieties. In the Bombay trade, characteristic colours, cleanliness or size were associated with Kathiawar or Dhollera quality (from Ahmedabad district), Khandesh quality, Indore Malwa, Gavathi and Warora, all place names. Taramira was called Duan or Seohan.

Sales were based on visual examination of samples sent by village merchants, and on some refraction guarantee as the basis. For example, for toria, a refraction of 4 per cent, with mutual allowances up to 8 per cent, and rejection thereafter, was typical. Both delivery and futures contracts were operative.

Incidentally, the three true mustard seeds, all called rai, were not used in the oilseed trade. *B. nigra* or black mustard was termed Banarsi *rai*, *B. juncea* var. *rugosa* was Pahadi rai and *B. tournefortii* was jangli (wild) rai.

Marketing of Coconuts and Coconut Products (1944)[76]

Supplies: On 0.6 million ha, India produced 3,000 million coconuts on an average, some 22 per cent of world production, during 1934 to 1939. Of this 41.3 per cent was in Madras Presidency, 37.8 per cent in Travancore state and 11.3 per cent in Mysore state (total, 90.4 per cent). An estimated average of 1.6 per cent of these were plucked when tender for their juice, while the rest continued to maturity. Some 15 per cent of the latter went for edible use, in the form of fresh gratings used in curries, chutneys and sweetmeats, as well as for religious or secular ceremonial functions of many kinds. About 46 per cent of all the nuts produced were used to make copra, the figure varying from 75 to 10 per cent in various producing states.

Copra: Milling copra was made in cup form, and edible copra as a whole ball; about 80 per cent on an average was used for the former purpose, intended for oil milling. Ball copra was made by fully drying out whole coconuts with the husk on, and cup copra by dehusking the nuts, breaking the nut into two halves, discarding the water and drying (details are given in Section 3.1, page 58). Copra was made either by coconut growers themselves, or by professional village copra-makers who bought the nuts, or by wholesale merchants from partly-dried material. Copra from stored coconuts was rated higher than from fresh. Producing one ton (equal to 1.016 metric tonne) of copra needed 6,222 nuts in the South Kanara district and 7,000 nuts in the Godavari district of Madras, 6,850 nuts in Travancore/Cochin and 8,000 nuts in Mysore. In Madras, the yield from 1,000 nuts was stated to vary from 173 to 136 kg, being high in February to May and low in July to November. To supplement the 200,000 tonnes of copra made in India on average during 1934 to 1939, some 46,000 tonnes were imported. Exports were negligible.

Prices: Big nuts fetched a better price than small, mature nuts a higher price than tender, and stored coconuts a premium over fresh. Ball copra, used for edible purposes, usually sold at higher prices than cup copra for milling. Coconut and milling copra prices were low between April and September, but edible copra held its price throughout the year.

Coconut oil prices, weight for weight, were generally 1.5 times those of copra, and coconut cake prices one-third those of copra. Coconut oil was generally more expensive than groundnut. Coconuts were often pledged on a chowdana basis. In this reckoning, all the nuts to be harvested over the year were sold in advance on the basis of one-third of the prevailing price of coconut oil for 1,000 nuts, a system stated to favour the buyer.

Marketing of nuts: The fresh juice of tender coconuts quickly turns brackish; hence for this use, nuts were quickly sold to hawkers, itinerant dealers, retailers and merchants for further movement by cart, lorries or country craft to a distance of 150 km or more. The producer received about 60 per cent of the price paid by the eventual consumer. Mature nuts could be sold fresh or stored, either whole or dehusked. Only whole nuts were stored. Dehusked nuts stored poorly and were only used to make milling copra. Storage for periods from one week to 12 weeks gave panicha or waternuts, which were graded by size or degree of maturity. Storage for four to six weeks in gardens in the shade yielded kotti sukha or dry nuts, graded by size and type of husking.

Assembly of mature nuts was effected by numerous agencies. Small producers took their material, either directly or through commission agents, to the village shandies or bigger markets. Big producers sold to copra manufactures, village merchants and wholesale merchants, either directly or through agents. Copra-makers bought coconuts at gardens (husking the nuts on the spot before carrying them away), or at markets from village merchants. Ghani-owners bought nuts from gardens or village shandies, and then made their own copra. Village merchants assembled nuts from gardens, while wholesale merchants and commission agents did so from gardens, shandies and bigger markets (either directly or through village merchants). The relative roles of these agencies varied in different areas. In Travancore and Cochin states, copra makers were by far the most important agency for assembling. In the Malabar districts of Madras, and the Ratnagiri district of Bombay, commission agents prevailed. In the Tanjore district of Madras it was mainly the producers themselves, and in Mysore, both producers and commission agents. There were many large markets for nuts, others for copra (Alleppey being by far the largest of these) and yet others for coconut oil and coir products. Certain markets had days when only coconuts were sold.

At Arsikere in Mysore state, an important assembling market, dehusked coconuts arriving in carts were heaped on platforms or in sheds, and auctioned by the seller's commission agent to market commission agents, sometimes buying on behalf of outside parties. The nuts sold were piled back into the carts, taken to the buyer's shop and counted in the presence

of the seller, defective nuts being rejected. The buyer was entitled to 1,100 nuts for the thousand paid for plus five extra, two of these being for the merchants' association, two for the counters and one for the labourers, the total commission charges being about 3.125 per cent. At other markets, buyers made open offers to the commission agents, or bid under cloth cover as described for groundnuts (p. 37). Charges varied greatly from one market to another, ranging from 3.3 to 11.1 per cent of the worth of the coconuts sold. On an average the farmer received about 55 per cent of the consumer price for mature nuts, the figure ranging from 90 to 38 per cent depending on the number of intermediaries, the maturity, etc.

Marketing of copra: Ball copra for edible use was made by slow drying of whole nuts. It was isolated and graded by place of origin (Calicut, Madras, Mysore) and by size. Cup copra was made by natural or artificial drying in kilns for edible use, and it came in several grades. In cup copra for milling, the best grade was called Vettumani or Office Pass; rejections from this grade were called Rashi, and in Mysore, Kavathu. The number of days of drying (four-day drying, or five- or seven-day drying) was used to differentiate grades, as well as the moisture content, which could range from 5 per cent, called Culter or fully dry, to 15 per cent.

Small village market (shandies) played practically no part in the assembling of copra. Important crushing centres both assembled the copra (brought by village merchants or wholesale merchants) and sold them (to oilmillers and wholesale merchants). Market charges varied widely from 0.7 to 3.6 per cent in various places, always payable by the seller.

Weights were variable. A candy connoted from 320 to 230 kg in various markets. In Mysore state itself, a satta meant 10 maunds of 31.5 lb each in one location, and 10 maunds of 25 lb each elsewhere. The common unit in north India was always the maund, but it could vary from 40 to 52 seers. On the west coast, where the coconut trade is largely centred, the stone weights commonly used were liable both to wear and to tampering.

Copra was packaged in old jute bags, called gunnies, and edible grades in new gunnies, or in gunnies with a lining of coconut strip matting to yield a circular package called a murha containing 84, 126 or 168 lb of copra. Transport was by shoulder sling (a time-honoured method), bullock cart, motor truck, country boat, coastal steamer, or railway.

Marketing of coconut oil: Owners of ghanis, called chekkus in coconut country, sold oil directly to consumers or to local retailers, and only rarely to more distant markets. Larger oil mills sold produce to wholesale merchants either directly or through brokers or selling organisations, or to commission agents at various centres. Retail business in coconut oil was in the hands of telis (oil mongers). Oil moved by all types of transport: road, rail and water. The packaging was in tins holding 36 lb, iron drums that held from 4 to 10 cwt (hundredweights, each equal to 112 lb), and wooden casks of cedarwood for the export trade from out of Cochin.

Marketing of coconut cake: Chekku owners sold the bulk of all the coconut cake produced. Mill cake was taken by wholesale merchants for

further sale to exporters, merchants at other markets, or retailers. Large mills in Bombay and Sind (now in Pakistan) sold directly to exporters also. Cake movement occurred by all available means of transport as earlier enumerated, the usual packing being a bag of 1.5 cwt (76.2 kg).

MARKETING OF GROUNDNUTS (1941)[77]

Availability: In the decade 1931 to 1940, the average annual production was 27.50 thousand short tons of groundnuts-in-shell, and the average yield 903 lb/acre (equal to 1,016 kg/ha). By 1940-41, production was 34.05 thousand short tons, of which the percentage share was: Madras Presidency 51.7, Hyderabad state 18.0, Bombay Presidency 17.6 and Bombay states (Gujarat, western India, Kolhapur) 8.8, total 96.1. Spreading varieties gave much higher yields than bunch varieties, and irrigation greatly raised output. Four types of groundnut were grown in India, though marketed under many names: Coromandel, Bold, Khandesh (or Peanuts) and Red Natal. These are described elsewhere, as also their regional distribution (see page 68). Some 15 per cent of seed produced was retained by producers, while 11 per cent went for sowing, 2 per cent for crushing in chekkus, and 1 per cent for consumption. Harvest labour was paid in kind at one-tenth to one-sixth of the produce, but even this quantity was frequently sold in the market for cash. Market arrivals were October to January, and an average of 47 per cent of all groundnut production was estimated to have been marketed for use in India between 1933 and 1938, to be utilised thus: oil extraction 42.5, for seed purposes 11.4, edible use 6.7 and export 39.4 per cent. Nut prices were influenced by several factors. Coromandel fetched a higher price than Khandesh, and machine-decorticated units a better price than hand-decorticated material, the difference being as much as 24 per cent in 1937-38. Peak prices were to be had in December and January and from June to August, and a deep harvest depression occurred from August to December, the spread being as high as 40 per cent in certain markets.

Market preparation: Whole plants of bunch varieties were pulled out, sometimes using a harrow; plants were stacked or tied in bundles, sometimes partly dried, and taken to the threshing yard for a further four-to-15-day drying period. Pods were twisted free by hand, or by beating the haulms with sticks, or by flailing them on the floor, after which the pods were picked free or winnowed from a height. Spreading-type plants were first cut down, and then uprooted using hand implements, harrows or ploughs. Seeds reaching the market were never fully dry. "The erroneous notion of the cultivators that they get paid for more weight by selling wet pods, and the need for cash, are largely responsible for this practice. Flooding the fields to make digging easier and save harvesting costs, or even sometimes to float out the pods, increases seed moisture."[77]

Some 3,000 beater-type groundnut decorticators, and about 2,000 grate-type units had by 1940 displaced the earlier practice of hand decortication using a flat paddle notched on one side. These are described elsewhere

(Section 8.2, Decortication). Decorticators were owned by wholesale merchants and established in large fenced spaces near railway stations or assembling markets, and would handle either nuts-in-shell bought by the owner, or contract jobs from commission agents. Many decorticators formed part of other industries, like thc ginning of cotton, or the milling of rice, wheat or pulses.

Assembling of groundnuts: The marketable surplus, constituting some 85 per cent of production, reached the market from producers (52 per cent, mostly in shell), village merchants (20 per cent) and agents of wholesale merchants, decorticating establishments and oil mills (15 per cent), the relative figures varying in different areas. Decorticating establishments in south India played an important triple role in assembling and distribution of groundnuts. As wholesale merchants, they bought and stocked nuts on their own account; as commission agents, they stocked and sold, either as pods or nuts, material brought to them by producers and village merchants; and as processors, they decorticated on contract and also undertook drying and bagging.

Cultivators, deeply in debt, had little option but to sell to their creditors, who might pledge their crops even up to 10 years in advance. Village merchants were small tradesmen (banias) working in a confined radius, who often advanced loans to cultivators and bought produce on behalf of wholesale merchants. Landlords sold produce that they received from cultivators in lieu of rent. Agents of wholesale merchants, decorticating establishments and village merchants bought from villages, and the first two at their own premises from producers and village merchants, to whom they might lend bags to fetch produce.

Market types, charges and practice: Primary or village occasional markets, called hat, painth or shandy, and secondary markets, called mandi or gunj, both sold groundnuts. The latter functioned as wholesale daily markets at important trade centres, in district or taluk headquarters, or near railway stations. Brokers, commission agents and traders visited these markets to transact business, after which the seller delivered the goods to an arhatiya's shop, where actual payment was made. Terminal or port markets for groundnuts included not only Madras and Bombay, but Gujarat ports and Cuddalore, at all of which exporters even bought directly from producers. Cuddalore port in fact was at once a primary, secondary and terminal market. Toll or tax at approved rates was collected from all produce entering the markets, which were owned by municipal boards, district boards, associations of local merchants or private individuals. Regulated markets were just beginning to take root: in them buyers, sellers, weighmen and all charges were licensed and regularised. The Commercial Crops Act was passed in Madras in 1933, and by 1940 there were 21 regulated markets in Hyderabad state and 36 in Gwalior state.

Market functionaries included kachcha (small) and pucca (big) adatyas with access to small or big capital. The former financed groundnut culti-

vators and village merchants, and the latter bought and sold on behalf of outside merchants by advancing from 70 to 90 per cent of the value. Many adatyas themselves owned decorticating premises, processing their own or others' nuts. Dalals or brokers not only brought buyer and seller together, but purchased for clients, kept records, showed samples of produce, canvassed sellers of nuts for their clients (meeting the carts before they reached the market), and reported to the keeper of records the rates and the number of cartloads sold. Minor functionaries were the weighmen (tolas or bays); the labourers who weighed bags and filled, packed and stacked them, called hamals or palledars; and the sweepers, water-carriers and so on.

Market charges varied from 3 to 13.5 per cent of the price of material sold, all payable by the seller. These charges included as major components commission and brokerage, and handling and weighment charges, but there were others. Tolls and taxes were paid on entering the market. A charge for charity could be as high as 3.9 per cent and was used to support homes for aged cows (called gowshalas), temples, and religious institutions. Quality allowances depended on moisture and impurities and, if high, could constitute as much as much as 20 per cent of the price.

Market practice commenced with the arrival of carts of nuts at the shop of the commission agent at 8 a.m. when transactions would start; they finished by 2 p.m., leaving the rest of the day for weighment and settlement. A handful of nuts would be chosen at random here and there, judged for weight, and then shelled so that the kernels could be squeezed, broken apart and bitten between the teeth to check their maturity, moisture level and oil content. In making bids, lots were either sold in open auction to the highest bidder with all buyers present, or buyers could make offers either to dalals who went round with samples, or at the adatyas' shop. In the cover system, different buyers clasped hands with the adatya under cover of a cloth, and indicated prices in secret by a system of pressing one or more fingers, after which the highest bidder was declared (Plate 3). After the deal, the produce was weighed at the adatya's shop or buyer's godown or factory, extra being taken in lieu of various payments, for example, for the temple, gowshalas or refractions. The seller was paid on the same day by the commission agent or owner of the decorticating factory after deducting market charges.

Distribution of produce: As shown in Fig. 6, the groundnut crop reached the ultimate user, in India or abroad, through a complex network that involved the cultivator, village merchant, decorticating establishment, commission agent and wholesale merchant, exporter, oil mill and a few cooperative societies. Cultivators assembled about half the marketable surplus, generally as nuts-in-shell, but also as kernels after decorticating by hand or machine. Village merchants operated similarly, while nuts were also assembled by agents of various agencies. At the distribution end, commission agents and wholesale merchants were prominent, keeping in touch with up-country buyers, buyers for exporters, and decorticating

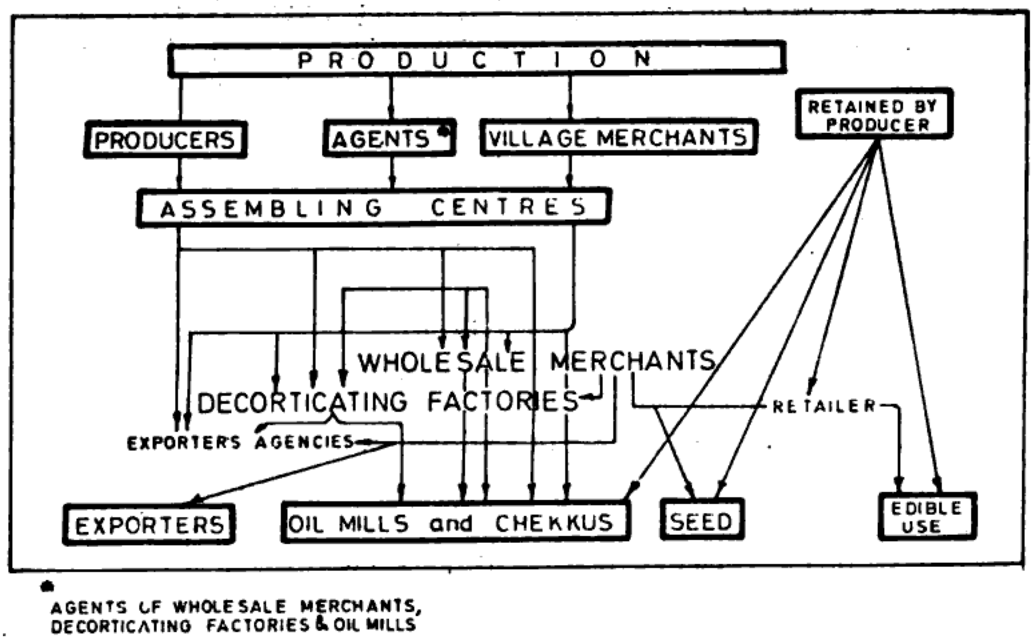

Fig. 6. Marketing channels for groundnuts in the 1940s (Source: Groundnut Marketing Report)[77]

establishments as well. Three large European firms controlled the export trade, all with headquarters in Europe, branches at all important Indian ports, and sub-agencies in producing areas. Exporters bought to strict contract specifications, paying after sampling and analysis. Both oil-millers and ghanis bought groundnuts-in-shell in assembling markets or through commission agents or wholesale markets, preferring to decorticate the pods by themselves.

Price spreads: The producer's share in groundnuts at different markets was about 66 per cent of the consumer's wholesale price, and about 45 per cent of the consumer's retail price. Cost of transport between a producing market, say Madhoganj in the United Provinces and an arhatya in Patna, varied between 18 and 32 per cent of the value of goods at the starting point; the main components of the cost increase were bags, between 15 and 27 per cent, and railway freight, between 57 and 68 per cent. Transport costs by cart and boat, where these could be used, were about one-fourth that by rail. Cost of export from Madras to London was 27 to 32 per cent of the price at the port of despatch, and the daily price variations at Madras port were sometimes large enough to offset price parities ruling at the other end.

Grading and standardisation were based on sampling of five or 10 bags of nuts; these were laid horizontally, cut open at the seams, and three scoops were taken from each bag at the top, middle and bottom. This mixed lot was cleaned to estimate impurities, and smaller scooped samples from the cleaned seed used to estimate the proportions of damaged, slightly damaged, shrivelled and immature nuts, and split and broken kernels, besides hooks (small pieces of broken kernels), the presence of castor seed, and any admixture with other seeds. Limits were set for each

of these, or for some collectively. Quality factors were the moisture content, percentage oil and free fatty acids in oil.

Trade contracts: Exporters worked to selling contracts of the Incorporated Oilseeds Association, London and Marseilles. These described Coromandel Groundnut Kernels for Crushing, and Bombay Kernels for Crushing. There were other contracts for hand-picked selected (HPS) groundnuts and kernels, for example, 38/40 FAQ sound delivered, or similarly 40/42. Exporters used other contracts for their purchases in India. These were of several types. In one the rates were fixed for a certain quality by both parties before entering into contract, in another sampling was at the exporter's godown at the port (this was called Agency Basis or Port Pass), and in yet another no price was settled at the start and the settler was obliged to fix a price within 60 days. Within India, contracts of the Grain Merchants' Association, Bombay, were in common use; these specified delivery at the buyer's godown (when 90 per cent of the price was paid) or at the seller's godown, with payment within 24 hours of weighment. Refractions of 4 per cent were allowed on each. Futures contracts of various trade associations, for example, the Seed Traders' Association, Bombay, and the Grain Merchants' Association were also based on 4 per cent refractions mutual, with allowances for excess.

Storage: In villages, groundnuts for sowing in the next season were always held as pods in earthen pots, mud bins, or bamboo or wicker baskets. Village merchants stocked pods in their houses or godowns, either loose or in jute bags. At the markets, godowns with hard floors, tile or masonry roofs, and brick walls were common for pod storage; the produce was heaped in bags, or loose on the floor covered with a tarpaulin, leaving a free air space of 1.3 to 1.5 m on top. Oil mills and ports also used similar kinds of storage in godowns, or sometimes even in the open or under tarpaulin cover. The dangers of moisture were well realised in 1941: "When nuts are stored without proper drying, or get wet, moulds develop on the shell in a short period, giving it a yellowish black appearance, and the kernels inside also get affected soon after." And again: "Moist kernels develop free fatty acids and rancidity more quickly and the oils from such kernels are reddish in colour with an unpleasant flavour." Damage from rats, beetles and weevils after poor storage was also noted.

Exports: During the period 1933 to 1938, annual production of groundnuts averaged 774,000 short tons, out of which 484,000 short tons, or 65 per cent, was exported. During the same period, out of 504,000 short tons of cake produced annually, 219,000 short tons or 42 per cent was exported. Of the 336,000 short tons of oil annually produced, 3,745 short tons or just over 1.1 per cent was exported.

Weights and measures: Weight and volume measures were used in the groundnut pod trade, but both showed great variability. The maund varied from 24 to 28 lb even in different parts of the Madras Presidency. The so-called Madras (volume) measure, also called Patnam or pucca padi, was usually 6.75 inches in height and 4.5 inches in diameter, holding 62.5

fluid ounces, but the weight of nuts that it held could vary from 11 lb 5 ozs to 11 lb 6 ozs (5.131 to 5.159 kg). The maund used in Mysore weighed 45 seers of 20 tolas, some 1.4 kg more than the standard maund of the same state; while the standard (volume) measure contained just about one lb of groundnut pods. In Madhoganj the maund had 50 seers, and in Nawanagar, 40 seers, each of 40 tolas, or half the railway maund (of 82.14 lb or 37.32 kg). For groundnut kernels, the maund used equalled 28 lb in Bangalore and 24 lb in Davanagere, both in the same state of Mysore.

The unit of sale for pods by volume in Madras was the putti, varying four-fold from 80 to 320 Madras measures in various parts of that Presidency. Other units were the kalam of 36 to 44 Madras measures, and the markal of four. In the Central Provinces, the palla (=3 maunds 6 seers) and khandi (=5.5 to 6 maunds) were used. Hyderabad state had several weight measures: the boja of 96 seers at Gulbarga and Raichur, khandi of 260 seers at Udgir, candy of 512 lb at Warangal, and palla of 120 seers at Bidar. Mysore had both a volume measure of 210 seers, and a weight measure, the satta of 8 Mysore maunds. While an English candy was 531 lb, and a French candy 529.109 lb, the candy in Kathiawar was 800 lb, in Bombay 500 lb and in Travancore 531 lb (though a copra candy was 654 lb!). A bag of groundnut pods was in frequent use, and held about a maund of produce; but in Kathiawar, this would mean 72 lb of HPS quality if Bold and 82 lb if Small.

Kernels also were subject to similar measurement vagaries. The Madras candy was 531 lb, but frequent use of bags as a standard implied from 164 to 200 lb of produce. Standard hundredweights (cwt) and tons were usual for oil and cake, but the Central Provinces had a tanki of 4.75 maunds as a volume measure for oil. Confusion in trade even within a state, and much more so between states, was frequent.

Recent Groundnut Marketing (1983)[78a]

Marketing of pods: Changes have occurred in the last 40 years in regard to groundnut marketing in India. The village trader procures pods at the farm, bearing all market costs. Sometimes he may give a loan to the farmer, but pays him after he has sold the produce in the market to a commission agent or to the oil-miller directly.

Regulated markets, some 3,500 all over the country, have totally replaced all the secondary mandi and gunj markets. All charges are regulated, the number of functionaries have been reduced, prices are posted, and the farmer is paid for his goods the same day. The commission agent charges 0.75 to 1 per cent of the pod value, and is paid by the oil-miller within three days. Storage charges are met by the farmer, as also transport charges to the market, but from market to oil mill is the miller's responsibility.

Either processors or wholesale merchants may recruit brokers to buy seeds directly from farmers. The two parties meet on a mutually agreed day, fix a price, and record the sale: this is called the janghall system.

Farmers are paid on the day the sale is recorded, at the price prevailing on that day.

The cooperative movement is making some headway among oilseeds growers, though sales through cooperatives are still small. Cooperatives act as commission agents, and the farmer pays less commission than to a private person. He meets all costs of transport, loading and unloading initially, but is paid back. The farmer today may frequently himself be an oil-miller or a commission agent for the produce of others.

Marketing of oil: New marketing channels for the oil have arisen. Within any state, the commission agent deals directly with the mill, but for movement outside, the broker intervenes. The broker claims his share from both the seller and the buyer, the rates varying from state to state. Commission agents are reckoned to handle some 70 to 80 per cent of all sales of groundnut oil. Wholesalers buy either from them, or directly from the oil-miller, selling in town to the retailer, who of course vends several oils for consumer use. During the 20-year period 1962 to 1981, it was estimated that the price paid by the consumer was shared in the following way (expressed as percentages): farmer 57.70, retailer 8.87, miller 25.27 and seed wholesaler 8.16.

Weights and measures: The metric system, both for weight and volume, has totally superseded all local practices.

CHAPTER 3

History of Indian Oil-bearing Materials

3.1 Historical Oilseeds (Group A)

Archaeological excavations of cities of the great Indus Valley culture which spanned the period 2500 to 1500 BC have yielded charred seeds of the sesame, and of a mustard, *Brassica juncea*. Cloth and string made from *Gossypium arboreum* have been found, so cottonseeds were known. A fossilised coconut has been recorded from Indian soil from the eocene period, some 50 million years ago. Thus some Indian oilseeds have a very long past behind them.

This section traces the origin of these historical oilseeds in India: the sesame, cottonseed, rape-mustard, linseed, coconut, castor, niger and safflower. The archaeological finds of these materials, their origins and arrival in India, the transformations that they may have undergone in the country, their mention in the literature of India, and the operations to which they are subject before becoming available to the miller for processing, will be considered for each oilseed in turn.

These eight historical oilseeds have been termed Group A in the rest of this book.

Production of these oilseeds in India in 1983-84, and of the oils obtained from them, is shown in Table 1.

A 1. SESAME

Archaeology

Excavation in the 1930s brought to light, in the hollow of a circular brick platform, "a quantity of lumped and charred sesamum" seeds[5] along with burnt grains of wheat and peas. These platforms were later identified as grain-pounding areas attached to granaries. Few other archaeological finds of sesame have been made anywhere in the world: Bedigian and Harlan[79] remark that this is not surprising, since the seeds are small and fragile, and hardly likely to survive except as a carbonised lump.

Literary record in India

The Aryans who poured into India as conquering immigrants from about 2000 BC must have encountered the sesame seed in the Indus Valley. There is some doubt whether the reference in the *Rigveda* (1500 BC) to pala is to the sesame, though the term is employed in compound forms later to refer to this oilseed. But the *Atharvaveda*, dated approximately at 1000 BC, repeatedly mentions the use as food of the tila, the usual term for sesame, in the form of a gruel or porridge, and also to the use of its oil, to which this book will return.[80a] The *Samhitās*, which closely follow the *Vedas* in point of time and are dated about 800 BC, repeatedly describe the uses of sesame seeds in numerous contexts, both secular and religious. The *Taittrīya Samhitā* even mentions a wild sesame seed (jartila) being used to make a porridge.[79] In the Vedic ethos, a strong ritual distinction was made between cultivated grains or kristapachya which were grown using the plough and were selectively termed anna, and uncultivated or wild grains that required no human exertion. For ascetics, or those who had renounced the world, or for persons observing fasts or vows, only non-cultivated grains were permitted as food. The word tila also denoted a mole or spot, perhaps from physical resemblance to the small, dark sesame seed. It also came to mean something very small, as in the saying: "Who steals a grain will steal a sack" (til chor so bajjar chor), and "to extract the utmost" (til til ka hisab).

Following Vedic times, the use of tila or sesame seeds in various forms runs through the literature of the centuries. A few examples will suffice.[81] Two of the early Upanishads (compiled before 800 BC) describe tilodana, a dish of sesame seeds and rice boiled in water. Another dish of sesame seeds, rice and milk is krsara. This is first mentioned in the *Arthasāstra*, a manual of statecraft written about 300 BC by Kautilya. Even today this dish is popular all over India as kheer. Mixed preparations of tila with pulses, especially masha (*Phaseolus mungo*, now called urad or black gram), also figure in the literature. Sesame moulded with guda (the gur or unrefined brown sugar of the present, also called jaggery) made up palala and saskuli (this was a fried preparation that also included rice), of which today's laddus are modern descendants. The story is told of a Buddhist monk who so coveted these sweets that he specially begged for them from a householder, and then had to apologise for his greed in an assembly of monks.[80b] In making laddus, small white sesame seeds, or dehusked black seeds, are preferred for both their flavour and appearance.

The early Buddhist canonical literature of the fifth and the fourth centuries BC is a mine of information on food and social life. So are the Jātaka tales, which tell of the innumerable lives of the Buddha in his previous births, when he was man, animal, bird and tree. These describe sesame powder, prepared perhaps after roasting sesame seeds to make them friable, as is still done.[80b] Parpatas, the papads of the present, are now usually made from thin batters of pulses tempered with natural alkaline salts, but tilaparpatas are described in the *Acaranga Sūtra* of

about 300 BC. Another great classic, the *Charaka Samhitā*, refers to shaped preparations of fine flours of rice or chickpea *(Cicer arietinum)* with sesame, which were then fried in oil. Charaka also mentions the use of the leaves and stalks of the sesame as a pot herb. The other great compendium of surgery, the *Susruta Samhitā*, mentions the excellence of sesame oil, and in a commentary on this work by Dalhana (c. 1100 AD), a dry vegetable dish using sesame seeds, called tilavikrti, is mentioned. As a purificatory rite, six actions are specified for orthodox Hindus, all involving sesame seeds. These are: bathing in water containing the seeds (tilodvarti), anointing the body with pounded seeds (tilasuayi), making a burnt offering of the seeds (tilahomi), offering the seeds to one's ancestors (tilaprada), eating the seeds (tilabhuj), and throwing out the seeds (tilavapi).[79] At ceremonies for the recently dead and for ancestors, sesame seed balls called pindas are even today an important ingredient.

Literary references elsewhere

Sumerian clay cuneiform tablets dated about 2300 BC carry references to oil rations, ritual offerings and seed loans which repeatedly mention an oilseed, se-gis-i.[79] Even though Helbaeck in 1966 threw doubt on the existence of sesame seeds in those areas until much later times, Bedigian and Harlan offer a wealth of convincing evidence to the contrary.[79] These included such considerations as the season in which the crop was raised, the soil in which it was grown, the dehiscence of the pod, the absence of a raised margin in sesame seed which differentiates it from linseed, and the rough markings on the coat of the sesame.

If the seed originated in India, as is likely, how did it reach the Mesapotamian valley? Trade contacts between the Indus Valley civilisation and Sumer in Iraq by 2500 BC are well-documented. Characteristic seals of the Indus Valley have been found at Kish in Sumer, dated mostly about 2400 BC but some even earlier.[10] The sea routes from the ports of the Indus Valley were either to Makran or Magan on the Gulf of Oman, or to the flourishing port of Elam in Iraq.[11] There was also a land route by way of the Indian north-west mountain passes of Kirtar, Bolan and Gomel.[10] The Harappan port city of Lothal traded mainly with Ur, where clay tablets have been found which describe the return of seafaring merchants with ivory and shell objects, and the carnelian beads which were then manufactured only in the Indus Valley town of Lothal.[9a]

Origin of the sesame plant

Earlier evidence had led to the view that the sesame was first domesticated in East Africa by the Mande or Agau people who lived in the headwaters of the river Nile.[82] Darlington asserted categorically that the sesame originated in Africa.[83a] Indonesia was suggested by de Candolle after he had spotted a wild form there.[84a] Watt recorded finding, in the hilly tracts of Bihar, and in the north-west bordering Afghanistan, sesame plants that had exceptionally large glands at the base of the short pedi-

cles; this feature is rarely found in cultivated plants, and suggested their being indigenous.[85a]

Very recently, striking evidence from several angles has been presented by Bedigian et al. that the progenitor of the cultivated sesame is an Indian species.[79,86] The species is *Sesamum orientale* var. *malabaricum*, which had been described in 1950 as the wild form of India.[13] It appears to have been noticed as early as 1689 by van Rheede, the great Dutch naturalist,[79] whose *Hortus Malabaricus* was based on knowledge mostly gained from three learned local priest-doctors of the time, supplemented by his own observations. Descriptions and drawings were presented of two species of sesame, "schit-ellu" and "car-ellu"; the latter was probably the wild sesame in question, and also the jartila mentioned in the very early *Taittriya Samhitā*.[79] At present car-ellu is the term used in south India to denote the sesame crop grown in April to June, and to contrast it with the pyru-ellu crop of January to March.[87a]

Specimens of this plant were found by Bedigian et al.[79,86] in all parts of India. In the Walayar Forest Reserve in Tamil Nadu it was found growing wild. A study of several hundred sesame plants grown from seed collected from all over the world showed that Indian cultivars, including the progenitor variety, all had a purple plant colour, bicarpellate capsule, intense pigmentation of the corolla, stem, leaves and capsules, and black seed colour.[86] As the plant travelled outwards from India, other traits became manifest through recessive genes. It was concluded that "the Indian subcontiment is the centre of origin," and that in India had arisen the genetically dominant purple plant colour and other associated characters.[86]

Names of the sesame

The origin of the Sanskrit word tila is uncertain. Certain words in Sanskrit (sarshapa for mustard, or narikela for coconut) are believed to have originated from languages that existed in India prior to the Aryan invasion. These could have either been the Dravidian group of languages, or the so-called Munda tongues of the many aboriginal peoples of India. From the se-gis-i of the Assyrians was derived the word sesame of both ancient and modern European tongues. The simsim of Arabic also stems from it, and Rumphius suggested that the current Arabic words semne for a fat or oil, and samnah for butterfat, originated also from se-gis-i.[84a]

Gingelly is used for sesame in south India even by early British writers. Orissa was known as the gingelly coast for the large quantity of sesame oil exported from it. Gingelly is believed to be derived from the Arabic juljulan by way of the words gergelim and zerzaline used by the early Portuguese and Dutch visitors to India.[85a] It has also entered modern Spanish as jonjoli and modern French as jugleone, while modern Arabic uses both simsim and al-juljulan. The latter word originated about the 8th century AD to describe the sesame pod before the seeds are removed. This has led to the suggestion that the root could be juljul or jeljel, which

both suggest the jingling of bells,[79] an apt enough description of the bell-shaped sesame capsule in which the seeds rattle when dry.

The very old Tamil word for sesame is ellu, a name that still persists. Perhaps the origin of this again lies in even older Dravidian or Munda tongues. The word occurs in the *Puranānooru*, a collection of works by 150 poets dated about the second century AD.[88a] Rather strikingly, old Akkadian also has same word ellu, meaning both pure and sesame oil.[79] Since the word is never found in conjunction with the term ku meaning pure, it is suggested as being a loan word from another tongue.[79] This language could have been the Dravidian of south India, from where perhaps the plant reached the Middle East.

Sesame oil

The current term in Tamil, the earliest language of south India, for oil from the ellu is nall-ennai meaning sweet oil. Two later languages have equivalents: achchellu in Kannada, and nuvvulu in Telugu. What makes this striking is that the Chicago Assyrian Dictionary, as meanings for ellu, lists fine oil, sweet oil and pure sesame oil.[79] Sudanese farmers refer to white sesame seed, grown for use as grain, as sweet, and to the red forms raised for oil as bitter, perhaps because of the higher tannin content of the latter. Of course the exceptional stability of sesame oil, a result of the presence of the natural antioxidants sesamol and sesamolin, probably accounts for its reputation for sweetness. In India, the oil from black sesame seed is preferred; to counteract its slight bitterness, jaggery (raw brown sugar) is added during crushing (see Section 7.5).

The resemblance between the Tamil ellu, thc Greek elaia for the olive tree and elaion for the oil, and the Latin oleum is also intriguing in that it suggests a common source.[89]

The Tamil work of the second century AD, *Puranānooru*, has the word ennai for sesame oil.[88b] An even earlier Tamil work of the second century BC, a grammar called *Tolkāppiyam*, has enn for the sesame seed and the word nai for its essence or extract (oil).[90] During later development, the term ennai became generic for any vegetable oil, with a prefix to indicate its source. Thus ellu-ennai was sesame oil, thenga-ennai coconut oil and ven-nai butter, while nai by itself stood for ghee (clarified butter). It is rather interesting to note that this is exactly what happened in Sanskrit, when the word tila for sesame seed gave rise to the term taila, first used for sesame oil and then generically for all oils. Yet this seems to have occurred over a millennium earlier in north India than in the south.

Sesame oil is the only vegetable oil to be mentioned in the earliest Tamil literature. The coconut and its oil must have been known very much earlier, yet the coconut (as will be seen) is mentioned, but not its oil. However the generic word nai (or essence) for oil, seems to have an even older derivation than sesame: as observed later, it is related to the name of the coconut in the Melanesian area in which the latter originated, and

in India got transferred from the nut to its extract, the oil (Section 7.1).

A 2. COTTONSEED

The processing of the cottonseed for its oil is of course barely a century old anywhere in the world, and even more recent in India. But the seed itself has long been in use as a cattlefeed, and the cultivation of the cotton plant for its fibre goes back a very long way in India.

Finds of cotton

Carbonised cottonseeds have been recovered from Mehrgarh, a 6000 to 4000 BC settlement in Baluchistan which is believed to have been a fore-runner of the Indus Valley civilisation.[91] A fragment of cotton cloth, probably dyed with natural madder, was found sticking to a silver vase unearthed at Mohenjodaro, the fabric having been fortuitously preserved by the action of silver salts.[92a] Small pieces of cotton string were found attached to some pottery; microscopic examination of the convolutions showed that this cotton was a typical *Gossypium arboreum*, which is still grown in India 4,000 years later.[1f] Numerous clay spindles and spindle whorls were found at Mohenjodaro, too small and too light to spin an elastic fibre like wool, but admirably suited to cotton spinning.[36a] In fact, some modern writers have speculated that the Indus Valley civilisation flourished because of the great demand for the cotton and its products that were raised, cotton goods being the main articles of the seafaring trade with the civilisations of Iraq.[91] Cottonseeds have also been found at Nevasa in Maharashtra in sites dated at 1500 BC, and cotton fabric impressions in prehistoric levels in southern Karnataka as well.[92a]

Literary mention

The Sanskrit word karapasi first occurs in the *Asvalayana Srauta Sūtra* of about 800 BC, where the material is mentioned as that from which is made the sacred thread enjoined on Brahmins, in contrast with silk and hemp.[85b] The *Arthasāstra* of Kautilya, about 300 BC, mentions cotton as karpasa and phalia, and lists the important cotton-growing areas of the country as northern Karnataka, Orissa and the areas on the banks of the river Narmada.[93] In the *Ramāyanā*, the five Pāndava brothers were presented with smooth, white cotton garments when they visited the western part of India.[93] Hudud al-Ālam, an Arab visitor of the sixth century AD, records that in Orissa and Andhra, cotton grew in large quantities on trees that yielded produce for many years.[93] The *Amarakōsha*, which can be placed at about 400 AD, mentions four varieties of cultivated cotton plants.[93] Of these karapasi was the commonest form, and the word stood for all other forms as well. The fruit of tundikeri had a sharp apex, and that of vadara was globose, like a ber fruit (*Ziziphus* spp.). Samundranta (samudra means ocean) was cultivated in the western part of India near the sea. Besides these there was a wild variety called bharadvaji. The

names for cotton in various languages, *sindhu* in Babylon, *sindon* and *carpasos* in Greek, and *carbasus* in Latin, are all of Indian derivation.[1f,85b]

When Alexander the Great entered India in May 327 BC, he brought with him a group of explorers who set down their observations of the country.[85b] The "wool that grow on trees" was a matter of wonder, even though cotton textiles had been carried to Europe and traded there long before anything was known about the source of its fibre. Theophrastus (350 BC) describes the whole plant as resembling the dog-rose, with leaves like those of the mulberry.[85b]

This description, the statement of Terry in 1619 AD that "the shrubs bear that wool for three or four years ere they supplant them", and mention by van Rheede (1686 AD) of cotton plants 10 to 12 feet in height, all suggest that Indian cotton was then raised on perennial trees.[94a] Even today the roji, a traditional variety raised in Gujarat, is a tall, bushy perennial with yellow flowers which yields natural brown cotton, and a seed heavy with lint which is also red in colour.[85b] In roji we have a relic of the perennial *Gossypium arboreum* race *indicum*, a progenitor of the annual *arboreums* of the present.[1f]

Evolution of the cottonseed

Perennial cottons are all susceptible to frost, and were therefore essentially tropical plants.[95] Four cultivated species developed in various parts of the world: *Gossypium arboreum* and *herbaceum* in India, *hirsutum* in Mexico, and *barbadense* in Peru. The first two were diploid with 26 chromosomes, and the two New World varieties tetraploid with 52 chromosomes. Archaeological evidence from Peru and Mexico suggests that domestication of the cotton plant had occurred in the New World by 5500 to 4500 BC,[96] while in the Old World it could have been about a millennium later. However the morphological range was even then sufficient to permit selection of early-fruiting forms: the latter then travelled to areas with temperate summers and cold winters, where frost in winter imposed on them an annual habitat.[95a] Selection for high cotton productivity completed the process. While wild cotton varieties are genetically uniform, there is enormous diversity in cultivated forms.

Gossypium arboreum, the annual Indian species of the Indus Valley, is believed to have been originally an African species. The wild ancestors are lost, but a white cotton with linted seed is found in the bush veld of South Africa and classed as *Gossypium herbaceum africanum*.[83b] This is believed to have first come into cultivation in Southern Arabia, where it still survives through an escape from ancient cultivation. Possibly it was carried from there by ancient Sumerian or Indian traders to the Indus Valley ports, and cultivated as a perennial.

The perennial *herbaceum* form resembles the *arboreum* very closely in morphological terms, except for differences in their fruiting parts, the bolls. There are also slight differences in the shape and form of the leaves. Genetically also the two forms are very close. The *herbaceum* form is

believed to have been evolved as *arboreum* cotton moved with the Aryan expansion into and across the Ganges Valley down the river.[83b] This probably happened both by crossing with native wild forms that are now lost, and by human selection. Later *herbaceum* moved overseas to Indonesia, and at the same time returned from India to its original African home. The *herbaceum* form was probably the first cotton fibre to have been spun and woven in Africa, at Meroe about 400 BC.

When the *herbaceum* type, now an annual and also cold-tolerant, entered Iran and Turkestan, new forms emerged. In the eighteenth century AD, these re-entered India through the north-west to provide even further cotton variety.[83b]

Mexican cotton, *G. hirsutum*, also developed annual types which however entered North America only in the eighteenth century.[83b] From there they went to many parts of the world, including India. Peruvian cotton, *G. barbadense*, with its fine long-staple fibre, developed rapid-maturing forms in its country of origin. These were taken in 1786 by way of the West Indies to the Sea Islands of South Carolina, where selection yielded Sea-Island cotton. Meanwhile a Peruvian perennial *barbadense* passed into Nigeria and thence by the slave route to Egypt, where it became extremely successful after 1820.[83b] This long-staple silky cotton, called in India either Egyptian, Sea-Island or Andrews, was introduced in the 1940s and acclimatised.[97]

Forms and varieties of cotton in India

Today about half of the 50 or so varieties of cotton grown in India are Old World types, *arboreum* and *herbaceum*, and the other half New World types, mainly *hirsutum* and a little *barbadense*.[97] These have been evolved either by hybridisation, crossing where compatible, and segregation or selection, to yield varieties suitable for the several cotton-growing tracts of India that vary vastly in soil and climate.

The Agro-Horticultural Society, founded in 1820 in Calcutta, set up among others a Cotton Committee of experts which in 1850 brought in many seeds to grow on their own farms. These included Sea Island, New Orleans, Seychelles, Upland Georgia and Bourbon cottonseeds from the U.S.A., Bourbon and Mauritius.[98a] Imported cottonseeds of various varieties were also distributed to 125 applicants from different parts of India. A year later Egyptian and Peruvian cottonseeds were imported for trial, and in 1841, the Society received 200 bushels of New Orleans, Upland Georgia and Sea Island cottonseeds and distributed them to branches of the Agro-Horticultural Society that had been set up in Agra, Bombay, Madras and Singapore. About 1875, the Lalbagh Gardens in Bangalore experimented with raising American Uplands, Fiji, Egyptian, Sea Island and Peruvian cottons.[98b] Even a dozen experienced American planters of cotton were brought out to India in 1840 to work in different parts of the country.[97a]

New Orleans cotton grown in Hubli in 1842 was a success; however between this variety and Upland Georgia, the latter proved more resistant to climate and insect pests.[97a] In Madras, Cambodia cotton became popular, and in Punjab both American imports and acclimatised Dharwar types proved successful after 1850. In Madhya Pradesh, Upland Georgia established itself under the name Buri. Egyptian *barbadense* varieties were eventually acclimatised only after 1940, especially in south Indian growing areas. Thus a very large number of varieties have established themselves at present in the various cotton-growing regions of India.[97a]

The Northern *hirsutum-arboreum* region comprises Punjab, Haryana, western Uttar Pradesh, Delhi and north-west Rajasthan, while the central *arboreum* region includes south Rajasthan, Madhya Pradesh, Vidharba, the Marathwada regions of Maharashtra, and the southern Saurashtra regions of Gujarat and Khandesh. The cotton region of the far south is essentially a *hirsutum-arboreum* one, comprising Tamil Nadu and Kerala, while the south-central states of Andhra Pradesh and Karnataka are *herabaceum-arboreum-hirsutum* regions. The western region, consisting of northern Karnataka and Gujarat, is essentially given to *herbaceum*, whereas the hilly eastern region, comprising Assam, Manipur, Tripura, Orissa and Bihar grows *arboreum* cotton in isolated patches or as perennial bushes in temple compounds.

Obtaining cottonseeds by ginning

The scientific staff who accompanied Alexander to India were so struck with the use of cotton that they described its cleaning, ginning, spinning and weaving in considerable detail.[86b] Two forms of gins have been employed in India from very early times. The foot roller, used on very hard-seeded varieties, consisted of a spindle-shaped iron piece.[84b] Cotton was placed on a large polished stone, and worked with this roller using the feet in a circular motion so as to push the seeds to the edges and thus card the cotton. The charka or hand roller consists of two wooden rollers, now sometimes made of iron, which revolve in opposite directions using a handle attached to a crank or wheel. The cotton passes between the rollers while the seed falls down in front.[84b] Modern gins improve upon this principle using water-power or steam.

Whitney's saw gin consists of a series of circular toothed saws which revolve within the interstices of an iron plate, through which the fibre is dragged leaving the seed behind. McCarthy's gin is of the beater type, the blade repeatedly striking the seed-cotton as it passes along a belt between metal plates which dislodge the loosened seed. By the turn of the century, cotton ginning mills worked by power had sprung up in India, numbering 951 in 1904. Seed cotton is known as kapas (from the Sanskrit karapasi), and ginning is carried out mostly in roller gins. These are double or single roller types, and the latter could have either a single moving knife or double moving knives. Saw gins were not much in

use in India in the sixties, but have since come into use in the Punjab cotton-growing area. The seeds removed are packed in jute bags.

Cotton seeds from the gins carry residual linters to varying degrees.[97b] *Arboreums* and *herbaceums* tend to be lower-linted (average about 4.5 per cent) than *hirsutums* (average about 10 per cent), but there is a good deal of overlap. *Barbadense* seeds are practically naked (linters 0.7 to 1.3 per cent, average 1 per cent). These cottonseeds form the raw material for processing to oil.

A 3. RAPE-MUSTARD

Archaeological findings and plant types

Carbonised seeds of *Brassica juncea* subsp. *juncea*, commonly known in India as rai, have been discovered in Chanhudaro (Plate 4), one of the cities of the Indus Valley civilisation, and dated about 1500 BC.[25a] Even today rai (otherwise called laha) is the major Indian species, constituting some 70 per cent of the total. Next in order comes brown sarson, which botanically is classed as *Brassica napus* var. *glauca* of which it is one ecotype;[99] the other is toria (*B. napus* var. *napus*), now occupying about 20 per cent of area. The third, called yellow sarson, is limited in quantity, being very susceptible to the mustard aphid. Brown sarson itself has two distinct types, loni which is self-incompatible and tora which is self-compatible.[99] Two other *Brassica* spp. are used as condiments but are not pressed for oil. These are *B. nigra* (black mustard, kalirai, Banarsi rai, or kadugu), a pungent variety used in pickles and curries. It was originally raised in England. *B. alba* or *B. hirta* or *Sinapis alba* (safed rai, white or yellow mustard), is originally a Mediterranean variety; it is a rarity in India, being mostly a garden plant, with large yellow flowers and a hairy stem. A related species, *Eruca sativa* or jamba, duan or seohan, is used in oil crushing as a minor constituent of the mix.

Plant and seeds of the *Brassica* species are traditionally well differentiated in India. In rai, *B. juncea*, the chief Indian variety, the leaves do not clasp the stem.[85e] The seeds are reddish-brown all over, rather small in size and distinctly rough. In plants of sarson, on the other hand, the leaves clasp the stem, the foliage has more bloom, the pods are plumper, and the plants are taller. The seeds are usually white, but when brown are easily distinguished from those of rai by the larger size and smooth coat, and from toria by a lighter colour and by not carrying, at the base of the seed, a pale spot characteristic of toria. The lotni type of brown sarson has mucilaginous seeds, while in the toria type, the seeds are non-mucilaginous. Toria is also called mogli and sarisha; the leaves clasp the stem (as in sarson) but the plant is smaller, while the seeds (like rai) are reddish-brown with a pale base spot, but larger and smoother.[85e]

The oils from these seeds have distinctive qualities, and the aim in crushing is to obtain a maximum out-turn of oil that is of the desired taste and the required pungent flavour.[100] This is achieved by crushing

mixtures of various rape-mustard seed varieties. Rai is of either high or medium pungency, and rather low oil content. Sarson has a high oil content. Toria has a low oil content, and the oil is considered to have a good taste but poor flavour. Typically, mixtures of 70 per cent rai and 30 per cent brown sarson, or 30 per cent rai, 30 per cent raida (a plump, purplish-brown rai variety grown in Rajasthan and Gujarat) and 40 per cent sarson may be crushed to yield oil with a high market value.

The pungency, flavour and sharp taste of rape-mustard oils is now known to be caused by various isothiocyanates. Glucosinolates that are naturally present in these seeds, through the agency of a thioglucosidase enzyme called myrosinase which is present alongside, when activated by moisture and heat, are cleaved to release various volatile isothiocyanates. These are the favoured products, though thiocyanates and cyanides plus sulphur are also formed.[101a] Rape-mustard seeds have been found to contain at least seven glucosinolates, which on hydrolysis yield the following isothiocyanates: allyl, 3-butenyl, 4-pentenyl, 4-methyl-sulphinyl-butyl, 5-methyl-sulphinyl-pentyl, 2-phenyl-ethyl and 2-hydroxy-3-butenyl. The last of these on release undergoes ring-closure to form 5-vinyl-oxazolidine-2-thione. In one study, the oilcakes of Indian rape-mustard seeds were found to carry the following quantities of isothiocyanates, expressed as mg/g of oilcake:[101b]

	Allyl	3-Butenyl	4-Pentenyl	Others
Rai	1.48	12.44	0.05	Nil
Yellow sarson	Nil	10.90	0.19	Nil
Brown sarson	Nil	13.43	0.10	0.29*
Toria	Nil	15.16	0.02	Nil

*Methyl-sulphinyl-butyl

However the belief still persists that allyl isothiocyanate is the chief constituent of various rape-mustard cakes. The varied spectrum would lend support to the historic Indian practice of crushing mixtures of rape-mustard seeds for a balance of taste and flavour. Even as a condiment, only rai will be used with fish dishes for its characteristic pungency, never the other varieties. It is also only the leaves of fleshy varieties of rai that are relished to make the spicy paste, wrongly called sarson-ka-saag, which is the traditional accompaniment to maize bread in Punjab.

Literary references

Mustard seed in early Sanskrit literature is termed sarshapa, a term believed to be of aboriginal origin. Two kinds of mustard seed were recognised. Rajika or black sarshapa is certainly the rai of today, but the

white seed, gaura- or sveta-sarshapa, also called siddharta, is probably yellow sarson, as suggested by Prain[102] and Watt,[84c] and not *B. alba*.

The seeds are frequently mentioned as food and medicine.[103] The *Atharvaveda*, about 1000 BC, uses the word abhoga for seeds that were employed to ward off supernatural agencies, and about the same period, the *Chandyōga Upanishad* and the *Sadvimsa Brāhmana* mention mustard seeds. Several books that make up the Sutra literature of 800 to 300 BC carry references to mustard seeds, like the *Baudhyāyana Grhya Sūtra* and *Sankhāyana Grhya Sūtra*. The Buddhist Jātaka tales of approximately 400 BC describe the use of mustard seed for seasoning food. White, black and red varieties of mustard seed are mentioned in the *Arthasāstra* of 300 BC, white mustard being listed as a spice. About the fourth century AD, the *Kashyapa Bhōjana* describes the use of mustard to import tang and pungency to a sour fruit juice concoction called raga.[103]

In later Vedic literature, mustard oil is believed to have been recovered by the nisadas.[99] This is a name given to the earliest aboriginal inhabitants of India, the word literally standing for turmeric (nisa) eaters (ad, to eat). Literary mention of the oil however is later than that of the seed, and the first indication comes in the Sutra literature of 800 to 300 BC.[103] This is not surprising, since the Vedic Aryans and their Brahmin descendants, as noted in the *Atharvaveda*, despised the oil as a cooking medium (Section 5.1), and the native Indian population left no literary records. The Buddhist canonical literature makes references to the oil, while the *Arthasāstra* (300 BC) lists it among the major oilseeds crushed. Charaka, in his *Samhitā* of about the first century AD, describes the use of the oil in food preparations. Both the Chinese travellers to India, Yuan-Chwang in the early part of the seventh century AD and I-tsing in the later part, make many references to the use of mustard oil in cooking.[103] I-tsing mentions the growing of large quantities of white and black seeds, and Yuan-Chwang refers to "parched grain with mustard seed oil" as an item of 'common food' then in Bengal, as it still is now. In the *Sukraniti* of the period after 750 AD, the use of mustard oil for frying is fully described. In a commentary on the *Charaka Samhitā* written in 1060 AD by Chakrapani Datta,[103] the many virtues of mustard oil are expounded; appropriately this work emanates from Bengal, where the use of mustard oil in the kitchen still holds pride of place.

The leaves and stalk of rai, as seen, are used as a pasty relish. The first mention of such use in literature is in the early *Acaranga Sūtra* of about 500 BC, and some 600 years later, the monumental *Charaka Samhitā*, a compendium of medicine, describes the use of the stalk of the black mustard (called āsuri) rather than the more common rājika, as a vegetable.[103] A later work, the *Astānga Samgrahā* of about 850 AD, does not rate these leaves very highly as food.[103]

The sacred and medicinal uses of mustard seeds will be described in Chapters 4, 5 and 6 of this book.

The evolution of the rape-mustards

a) Rai or *Brassica juncea* was long surmised to have had its origin in China and then to have entered India by the north-west pilgrim route of the Buddhist monks. Wild forms were thought to grow all along this route, but this species, once classed as *Sinapis patens*, is now regarded as *Nasturtium indicum*.[99] Wild forms were also believed to grow on the Kirgiz steppes, thus supporting this view. Another theory placed the origin of *juncea* in the Fertile Crescent of the Middle East, with centres of further diversity in China, Asia Minor and eastern India.[84c,85c]

Recent studies have altered this perspective.[99] Two races of *juncea* have been posited on the basis of biochemical evidence. One race is Indian, and the other is that found elsewhere in the world, including China. *Brassica juncea* has long been known to be a tetraploid with 36 chromosomes. These have been derived from two diploids, *Brassica nigra* (2n=16, AA) and *Brassica campestris* (2n=20, CC) the nuclei of which after fusion did not separate at the mitotic stage;[104] this is a phenomenon that occurs naturally and has also been experimentally achieved in brassicas to create new plants.[83c] *Brassica juncea* must have arisen in this way in prehistoric times in the Middle East, when *campestris* came in contact with *nigra*, thus accounting for its "wild" form in the Asia Minor plateau and in southern Iran.[99] Once it entered India with people migrating through the north-west, *juncea* became better adapted through introgressive hybridisation incorporating adaptive gene complexes. Equally *juncea* could have been born in the Himalayas, where both *nigra* and *campestris* exist, by simple chromosome doubling or by recombinant chromosome gametes followed by parthenogenesis. Since Indian *juncea* forms are all oil-bearing, it is surmised that only oleiferous forms of *campestris* took part in the marriage.[99]

The leafy form of rai used as a vegetable may have originated in China, and been brought by pilgrims to the Himalayan foothills. This form was once classified as *B. rugosa* or *Sinapis rugosa*, and called pahari rai, pasai, or the cabbage-leaved mustard.[85c]

b) Brown sarson, which is one form of wild *B. campestris* subsp. *oleifera*, must have originated from wild *campestris*, which is found all the way from western Europe to eastern China. Protein studies have shown the existence of two races, and one view is that Indian brown sarson evolved from the original stock in north-western India. Another is that it reached India already partly differentiated in Iran, since forms that closely resemble Indian forms grow there, and Persian synonyms of names also exist.[99]

The wild form of *campestris* is self-incompatible and the Indian lotni must thus have been derived from it. Tora, the self-compatible form, may have sprung from hybridisation between lotni and yellow sarson somewhere on the Gangetic plain; such hybridisation has indeed been effected artificially.[99]

c) Toria, another *campestris*, appears to have arisen by simple selection from a population of brown sarson.[99]

d) Yellow sarson has nowhere been found in the wild state, and it may have arisen from brown sarson, which it resembles. It is almost totally an autogamous plant, the degree of outcrossing being just 5 to 12 per cent.[99] It was established even by 1000 to 800 BC, being then called siddhartha. This may have occurred in north-eastern Indian, the yellow seed colour having perhaps been chosen for an attractive appearance, or for some flavour appeal in cooking.

A 4. COCONUT

Origin of the coconut

Burkhill in 1935 presented three theories of the origin of the coconut palm.[105] Two of these postulated a New World origin: one in the northern end of the Andes in tropical America, and the other on the coasts of central America. Both these have now been more or less abandoned in favour of the third which he had then advanced, namely an origin in South Asia or the Pacific. Today a Melanesian origin, perhaps in a land area near Indonesia and the Fiji Islands, now submerged, is generally accepted on several grounds.[107] Fossilised coconuts have been found in Magonui in North Auckland, New Zealand, in pliocene deposits. Even if this is a miocene find, as has been argued, it does mean that the coconut was fully evolved 15 to 20 million years ago, long before man appeared on the scene.[106] Of the insects specific to the coconut, 99 per cent occur in Melanesia, against 4 per cent in Africa and 20 per cent in America. Of particular importance is the coconut crab, *Birgus latro*, whose body fat resembles that of the coconut and which is unknown in America and the African mainland. There are as many as 50 varieties of coconuts known by different names in the Marquesas Islands.[106] In Indonesia there are 180 names for the coconut.[105] Polynesia has 30 names for various stages of growth of the coconut palm, from the female flower to the dried seed nut.[106] Though names resembling the Sanskrit narikela do occur in Malaysia, they seem to be older than the Sanskrit-derived terms,[105] and the Sanskrit word is itself pre-Aryan. Many legends in these areas centre round the coconut palm. The use of the coconut scraper of characteristic design occurs in the same areas as do outrigger boats. Thus a Melanesian origin seems likely, more specifically an area northwest of Papua New Guinea between 145° and 180° East longitude.[106]

History in India

A fossilised coconut has been recovered from deposits dated to eocene times, about 50 million years ago, from Rajasthan in north-central India when this area lay under the sea.[105,108] One of the jewellery pieces,[109] and an earthen bowl[110] found in the Indus Valley could be representations of a

coconut, though this identity is not unequivocal.[80f,109] The four Vedas do not mention the coconut, and indeed it is not till after 300 BC that it is referred to in a number of Sanskrit literary works, like the *Ramāyana*, *Mahābhārata* and *Vishnu Purāna*.[105] This had led to the suggestion that the coconut was first systematically planted in India on its east coast only about the first century BC, and reached the west coast perhaps a century later. The late adoption of coconuts into Hindu ritual may appear to support the view. The famous *Periplus of the Erythrean Sea* written by a Greek sailor from Alexandria about the middle of the first century AD describes the seafaring trade of India but fails to mention the coconut.[110] Is the coconut then a late arrival in this country?

The coconut is frequently met with in the oldest Tamil literature, though this is admittedly only about the beginning of the present century. A Tamil poem of perhaps 200 AD describes a village festival thus:[42g]

"In the cool woods, where the bees seek flowers,
Women, bright-bangled and garlanded, drink
The juice of the palm, and the pale sugarcane,
And the juice of the coconut that grows in the sand,
Then, running, they plunge into the sea".

An inscription from Nashik dated 120 AD registers the bequest of a cave by Usvadata, son-in-law of the Kshaharata King Nahapana, of a cave to a community of Buddhist monks, together with endowments of money (invested in two guilds of weavers) and a plantation of coconut trees (narikela).[60c] This would show that such plantations were in existence in 120 AD even so far from the traditional southern home of the coconut. The *Mahāvamsa*, a history of Sri Lanka compiled in the fifth century AD, makes particular mention of the plantations of coconut on that island by King Agribodhi II in 589 AD.[108] These may have been the first plantations of the palm there, but it does not mean that the trees were unknown on the island. In fact there is a reference to coconuts in Sri Lanka by Megasthenes (300 BC), which is only slightly vitiated by the fact that it has come down to us as a quotation in the work of Aelian five centuries later.[105] Possibly organised coconut planting in India also may have been a late development.

Names, and the movement of nuts

The Tamil name thēngāi has been interpreted in two ways. One is as a joining of thēn (honey-sweet) with kai (fruit). The other is from ten, meaning south, and suggesting entry of the coconut into south India from a southerly direction.[110] This has been assumed to be Sri Lanka, but could be Melanesia. The Sanskrit term is narikela, and philologists hold that this is an even older word assimilated into Sanskrit from the tongue of the Munda inhabitants.[80c] If so, the coconut in India predates even the Aryan influx of 2000 BC or so. The state of Kerala in the far south

of India was the ancient Chera, a name thought to derive from kayir for coconut fibre, also the source of the English coir.

It would appear from the origin of the coconut in Melanesia that its name in Sanskrit has an even hoarier origin. The Polynesians use the word niu for coconut oil, the Malaysians niyor and the inhabitants of the Nicobar Islands ngai.[110] In the Taraeng speech, kolai is fruit, and the origin of the Munda, and later of the Sanskrit, narikela has been postulated to be "from equivalence of niyor and kolai combined."[111a]

The Sanskrit term indeed followed the coconut round the world, which led to belief in an Indian origin for the palm.[85d] Marco Polo (1290) called it *Nux indica*, the Indian nut, and noted that in Sumatra it was termed Argell. Sir Francis Drake visited the Cape Verde Islands off the coast of Nigeria in 1572 and recorded the local name nargil for the coconut.

The pinning down of the English word coconut is most generally attributed to Barros in 1553, who stated that Portuguese seamen used the term "coco, a name applied by women to anything with which they try to frighten children; and this name has stuck because no one knew any other."[106] The husk of the coconut, when stripped, leaves a human face with two eyes and a mouth, quite appropriate for a hobgoblin or coco in Spanish. The logbook of Vasco da Gama (1498-99) notes that he boarded a vessel on which was found provisions that consisted of coquos, and Magellan used cocas to describe the fruits of the coconut palm. There is also a suggestion, originally due to the botanist Rumphius (1750), that the Arabic word djanz, pronounced ganz or goz, became goz-goz and thence coco.[106] In English, the Latin form cocos became botanised to Cocos, which yielded coco in ordinary speech. Samuel Johnson's Dictionaary of 1755 confused things by running the entry on coco together with the article on cocoa. This spelling still sometimes persists, though the British Society of Public Analysts even in 1914 firmly differentiated the spelling of coconut oil from that of cocoa butter.[106]

The dispersal of the coconut palm

How far did coconuts distribute themselves by floating round the world, and what part did human agency play? If the former could occur, it would explain their dispersal from the area of origin throughout the Pacific and South-East Asia. The balance of evidence suggests that this is possible.[106] Thor Heyerdahl on the Kon-Tiki expedition found that coconuts held below deck and washed by seawater were ruined when brine was sucked in through the eyes, which had softened. Yet in a trial in Hawaii, nuts floated in seawater for 116 days were still viable, during which time they could have travelled 5,000 km; the husk had absorbed seawater, but the young shoot was unaffected. Between 1928 and 1930, an island was created in Krakatoa by volcanic action; a scientific expedition which visited it subsequently, the first human beings to do so, found 41 germinating coconuts lying about the beach in a disorderly manner, mostly unburied, and remarked that "no one questions

their distribution by sea". Of course predators like wild pigs and fruit-eating bats which occur on many mainlands could make it less favourable for the coconut to establish itself than on lonely islands.[106]

Human agency too must have played its part in dispersal. Thus while Vasco da Gama found coconut palms on the island of San Jorge in East Africa, they did not reach West Africa till the Portuguese carried them round the Cape of Good Hope.[106] The mariners of ancient Tamil Nadu and Bengal who colonised so much of South-East Asia in the first few centuries of the Christian era must have played their part in the transfer of coconuts to and from India.[108]

The coconut in India

The usual range of occurrence in India is between 25° North and South latitudes, but this can be exceeded in the immediate basins of large rivers. The palms will grow in Assam, which is 26° North, but fruit indifferently. From Bombay city, on the west coast of India, the coconut will grow up to some 130 km inland, but in the South, they do extremely well around Mysore city which is twice that distance from either coast line.[85d] The state of Kerala is richly covered with coconut palms.

Seven forms of nuts have traditionally been recognised in India.[85d] These are: (1) the Coromandel or Brahmin nut, a yellowish-red form, (2) the Kanara, a very woody ovoid nut, (3) the Malabar, (4) the Maldive, small and spherical, (5) Achem, small and ovoid, (6) Nicobar or pointed nut, the biggest of them all, and (7) the Ceylon nut. The Brahmin nut is esteemed for its milk but yields inferior copra and coir. The Ceylon nut comes in two forms. One is the King Coconut, a golden-coloured fruit, the tree rarely rising above 6 m in height, and the other an even shorter dwarf variety.

For oil milling, the coconut has to be converted to copra. In many countries practically all the coconut is thus dried, but in India some 60 per cent of coconuts are used fresh in several ways.[112] The juice from the tender nuts, bunched on upright stakes, is sold as a refreshing beverage. The fully mature fruit is dehusked and the inner nut sold, the white flesh being used in a variety of foods, like the ground chutnies used as relishes, or Indian sweetmeats, or in grated form as a topping. Coconut 'milk' is squeezed from the grated material after wetting with water, and used to thicken, sweeten and flavour the curries of south India. Just 40 per cent of coconut production is converted to copra. Of this about a fifth is edible ball copra, and the rest cup copra for milling.[76]

Copra is traditionally made through sun-drying.[112] The mature nuts are dehusked on a sharp metal stake anchored firmly in the ground. The inner nuts are then held in the palm of the hand and struck with a sharp heavy knife to break them into two pieces, the inner water being simply thrown away. The halves are drained and then laid on a mat facing the sun for six to seven days, when the moisture content is reduced from about 45 to 6 per cent. The nuts get detached from the shells after two

or three days, but drying is continued. It is essential that the nuts dried be mature; if not, a rubbery copra will result.[76] To make ball copra, the nuts are put away for eight to 12 months on the eaves of the home below the roof, and the loose dry balls recovered by breaking open the shells.[76]

During the monsoon sun-drying is difficult, and rain frequently interrupts the drying process. Microbial infestation occurs with *Aerobacter* and *Bacillus* species, *Serratia marcascens* and *Staphylococcus aureus* among the bacteria, and moulds like *Rhizopus nigricans* and some species of *Aspergillus, Penicillium* and *Diploidia.*[112] Traditionally, sun-drying was supplemented by drying over an open flame in a small room, in which a brick platform some 1.75 m high ran along one side with a grill on top made of split bamboo or areca palm slats (Section 2.5, p. 32). On this is placed the coconut cups to a 20 to 30 cm depth, to be dried for four to five days by hot air and smoke from the smouldering fire raised on the floor below using coconut shells as fuel. The hot air that rises escapes through the thatched or loose-tiled roof. Sometimes the copra is stacked in jute bags in an airtight room and sulpur (0.5 kg per tonne of copra) is burnt in the room; such sulphuring ensures good storage during the next three months even through the heavy rainy season of Kerala.[112]

Indirect driers are described in Section 8.2 under the head 'Drying and Stabilisation'. Such drying is usually carried out at the oil mill just before copra milling. All the other operations described earlier are organised either by coconut producers who use their own coconuts, by professional copra-makers who buy the nuts, or by wholesale merchants who may buy partly-dried nuts and finish the operation.[76]

Using the large nuts of Kerala, 6,320 coconuts yield a tonne of copra; in Karnataka, 8,130 are required for a similar yield.[76] Sliced cup copra is the raw material used for oil-milling.

A 5. LINSEED

Archaeological finds and literary usage

Two settlements, both situated on the banks of rivers, and not too far from each other, have yielded grains of linseed (Plate 5). The site at Navdatoli in the Nimad district of Madhya Pradesh is on the river Narmada, and is dated between 1660 and 1450 BC.[25a] Linseed grains were also found in a 1000 BC layer at Daimabad, a chalcolithic settlement in western Maharashtra on the bank of the river Pravara, a tributary of the river Godavari.[113] A find of unusual interest, in the light of later evolution, was that of spun fibres of flax identified in a string of beads from a burial dated about 1400 to 1200 BC in Chandoli in the same area.[92a]

Around 500 to 300 BC, the linseed is mentioned under the name atasi in several works of literature: In Buddhist canonical works, in Jain canonical texts and in the *Arthasāstra* of Kautilya, where it is listed as one

of the oilseeds that is crushed.[80d] Among the various other Sanskrit names used for the oil are uma, ksuma, haimavati and marsina. Thus the *Susruta Samhitā* described atasi oil as being used for poultices, as having a slight smell of flesh, and as being pungent, light, penetrating and laxative. There can be little doubt as to its identity as linseed oil.[85e]

The same cannot be said of flax or linen, the fibre from the linseed plant. In the great code of laws, the *Manusmriti*, which is placed at about 400 BC, it is enjoined that the garments of students during their period of apprenticeship should consist of skins above, and of fabrics below like hemp, wool or ksuma.[85e] These same items are prohibited for sale by a Brahmin if he goes into business. Purification of ksuma fibre, presumably by bleaching, is also referred to. Yet in modern times use of linen fibre is practically unknown in India, and even early British writers from about the beginning of the sixteenth century, who frequently mention flax, the linseed plant, and linseed oil, never allude to its use for spinning fibre. In fact the many attempts made by British colonials to raise flax in India between 1790 and 1820 AD were deemed to have been a failure.[85e] It seems probable from the Chandoli find that the plant was indeed raised in India for its fibre during Vedic times and later, but subsequently neglected; the outlet may have been revived to some extent following the interest shown by the Mughal rulers after 1556, and later by the British. Even linseed oil was not a product in much demand by Indians. As late as 1900, only about 5 per cent of the production of linseed oil was used in India, and it was claimed that "the linseed of India is grown purely and simply in obedience to foreign demand."[84d] This changed of course with the rise of the ready-mixed paint industry about the time of the First World War (Section 5.3, Paints).

Evolution in India

The linseed is a very ancient plant. Excavations during 1963 to 1969 at Deh Luran, a site in western Iran at the south-eastern tip of the Fertile Crescent and separated from Iraq only by a low mountain ridge, revealed linseeds in all the three layers excavated, dated from 7500 to 5600 BC.[114a] Particularly large seeds, a result of presumed irrigation, were found in a slightly later adjacent site. Originally the seed was the perennial *Linum bienne*, earlier termed *Linum augustifolium* (which is still found wild south of the Alps), but at some unknown but ancient point of time this yielded *L. usitatissimum* of annual habit but the same chromosome number (2n=30). These species were developed in Europe into tall, straight, unbranched plants well-suited to the production of flax fibre.

In India, evolution proceeded on oleaginous lines.[84d,85e,115a] In the north, the *usitatissimum* type crossed with *L. strictum*, an annual herb with yellow flowers and globose capsules found in the north-west Himalayas, to yield one ecotype, the so-called yellow type. In the plains, crossing occurred with one of two forms: either with *L. perenne*, a perennial herb with blue flowers and large pods now found wild both in the

north-western Himalayas and in south India,[116a] or with *L. mysorensis*, an annual yellow-flowered herb with small flat oval seeds found both on the Deccan plateau of south India as well as in the western Himalayas. *Linum mysorensis* has recently been shown to have a seed oil of I.V. 59.6 which carries just 0.6 per cent of linolenic acid;[116] since Indian linseed oil averages over 55 per cent linolenic acid, such a crossing in the past does not seem likely, and *L. perenne* is to be favoured. In the event, two distinct ecotypes emerged in India. One is the quick-growing Indo-Gangetic alluvial type, with a shallow but abundant root system, and seeds of small to medium size rather low in oil but produced in abundance. The other is the Southern Peninsular type, deep-rooted, with bold seeds of considerable diversity, low in yield but rich in oil. Both are the same species, and even the south Indian names (alshi, agashi, aishi) resemble the Sanskrit atasi.[117] Flowers vary in colour from blue to lilac, white with a blue tinge, and white. It has been surmised that blue flower colour is prominent near the places of origin of linseed; as the species moved away, selection for economic benefit promoted associated recessive genes manifested in a range of colour.[78a]

Linseeds themselves in India are usually brown in colour, whether small or bold. Cream-coloured seeds tends to be bold, and to have a thinner skin and a higher oil content; the factor which turns cream-coloured seeds to grey, and fawn to brown, also causes an apparent depression in oil content.[78c] Bold seeds may weigh just 112 to the gram, but even figures of 135 to 150 are commonly classed as bold.[74] Small seeds could weigh 200 to the gram.[74]

To encourage branching, and hence profuse flowering and seeding, linseed plants are thinly sown in India.[74] The plants when mature are uprooted or cut by hand, threshed in a flat area (beaten down and plastered with cowdung) by trampling under oxen, and then winnowed. The straw is useless as a fodder, being actually toxic to cattle. This may be through the presence of the same cyanogenic glucosides known to occur in the seed, which can yield as much as 50 mg of hydrogen cyanide from a 100 g of seed.[116a]

A 6. CASTOR

Occurrence and mention in India

The only archaeological find of castor seed so far in India is of a really late date. Excavations at Ter in the Osmanabad district of Maharashtra yielded unmistakable castor seeds in layers dated 150 BC to 100 AD.[25a] Literary mention is however much earlier. The tagadbhanga of both the *Atharvaveda* (c. 1000 BC) and *Kaustika Sūtra* (500 BC) is believed to refer to the castor.[118] *Sankhāyana Āranyaka*, one of the forest books of about 800 BC, mentions the castor seed by its commonest name eranda, as does early Buddhist canon (c. 400 BC).[85f] Eranda is one of the oilseeds recorded as being crushed in the *Arthaśāstra* of Kautilya (c. 300 BC),[36d]

while about three centuries later it figures in the *Susruta Samhitā* as hastikarn.[85f]

Other Sanskrit names are also used for the castor seed. These include chitrajiva (from the pattern on the seed), panchangula or five-fingered from the shape of the leaf, vatari (enemy of rheumatism) and ruvaka.[119] The names in many languages in India resemble the Sanskrit eranda, and the latter is surmised to have been an aboriginal name absorbed into Sanskrit, and therefore ancient.[84e] The Indian names are quite unconnected with those of Africa, or of ancient Egypt, Greece or Rome; in Arabic the common term for the castor seed is sim-el-Hind or sesame of India. Even early Muslim writers in India from about the tenth century AD never refer to the castor plant and seed by Arabic or Persian names.[84e] The medicinal properties of the seed and its oil were not known outside India, suggesting its late presence elsewhere. In Latin the dog tick and castor share the common term *ricinus*. The English name castor derives from the use of the term *agno casto* by the Portuguese and Spanish in Jamaica through mistaken identity for another plant, *Vitex agnus castus*, and London traders popularised the common name castor.[84e]

Types and forms

The castor plant is "found wild with certainty", as de Candolle expressed it, only in Ethiopia, Seenaar and Kordofan. A recent review is of the opinion that the castor plant originated either in Ethiopia or the Fertile Crescent of the Middle East, and since the capsules are capable of being spread by sea, there are many centres of variability all over the world, including India.[119a] Seeds have been found in ancient Egyptian tombs, and the word used was kiki.[84e] It occurs in nearly a wild state in the scrubby jungles of the outer Himalayas. As Watt points out, it is never found in an Indian primaeval rain-forest, but only in jungles, often in association with two other plants, the Indian citron *Citrus medica* and the drumstick tree *Moringa oleifera*, both of which are likewise absent in Indian rain-forests.[84e] The plant is highly variable; Muller a century ago described 16 forms, and Popova a half-century ago six subspecies.[120] Yet all forms hybridise freely and are all without doubt *Ricinus communis*. The stems may be of various colours: mahogany, red, bronze, bluish-red or green.

From early times Indian writers such as Suṣruta (about 100 BC) describe two main types.[84e] One is a tall, perennial type with large shining red-brown seeds giving a high yield of an oil described as dark and inferior in medicinal terms. The other is a short plant, annual in habit, with pale grey or light brown mottled seeds, less rich in an oil of superior quality. Each of these forms may have several variations in the colour and shape of the leaves, the presence or absence of spines on fruit, capsule size, and seed size, colour and markings. A beautiful variety grown for ornamental purposes has large shining bronze leaves. There used to be persistent mention of a third form with smooth fruit which was stated to yield an edible oil. A century

ago Watt was shown such a specimen in Ahmedabad whose oil was stated to be used in cooking, and whose leaves were suffused with a white powder.[84e] No edible variety is now recognised, and its existence would be an oddity considering that it is not something extraneous, but the glycerides of a hydroxy acid constituting over 90 per cent, that are responsible for the purgative effects of castor oil. Use of ordinary castor oil in cooking is not unknown, but only for speciality items and in small quantities, in which the oil is absorbed and metabolised along with bulk foods.

In the last two decades, castor plant mutants have been bred by irradiation and selection with many desirable seed characteristics like short plant height, early ripening, uniformly-maturing spikes, and non-shattering capsules. These have been combined with an increase in the proportion of male pistillate spikes from the usual 30 per cent to upwards of 92 per cent.[121] These varieties, called Aruna, Bhagya, Soubagya and GCH, have dramatically raised the output of Indian castor seeds with little increase in in the area of planting.

Isolation of seed

The crop is gathered when it is just dry and before it shatters, three to four pickings being given during one to three weeks.[122] The fruit heads are either cut or broken off. The capsules are herded in a corner of the farmer's house. They are generally covered with straw or cloth to keep out air, with a little water sometimes sprinkled on the heaps. After six days the capsules soften and the shells decay, after which the seeds are exposed to the sun for two to three days. The capsules are then beaten with a mallet to release the seeds.

In North India it is a common practice[122] to bury the capsules for a few days in a pit (this is sometimes a dung pit warm through fermentation),[85f] followed by sun-drying.

Direct drying of capsules in the sun without storage is also known. There appears to be a belief that capsule storage raises the yield of oil.[122]

The seed may even be cleaned in the assembling markets (p. 29 and p. 36) before despatch in bags to the crushing centres.[122]

A 7. NIGER

Origin and Indian names

The niger plant, *Guizotia abyssinica*, as both its common and Latin names testify, would appear to be a native of Africa.[85g] This is perhaps the Ethiopian region from which India received, at some unknown period in the past, other valuable staple foods like the sorghum (*Sorghum bicolor*), ragi (*Eleusine coracana*) and bajra (*Pennisetum typhoideum*). If the niger seed indeed came with these, it must have been a long time ago, because sorghum grains have been found in Ahar, Rajasthan (1725 BC) and Daimabad, Maharashtra (1700 BC), with a somewhat doubtful representation even earlier in Mohenjodaro. Ragi and bajra have both been unearthed at Hallur, Karnataka (1600 BC), and bajra at Ahar, Rajasthan

(1725 BC).[25a] One path for the transfer of these species was the direct sea route from East Africa to Gujarat by way of the historic Sabaean Lane. Early immigration from Africa to western India has been argued on grounds of language and race,[123] and actual skeletal evidence has been discerned in the microlithic cultures of Gujarat of about 6000 BC.[124]

Many of the Indian names of the niger seed seem to resemble those of other Indian oilseeds.[85g] Sesame in Sanskrit is tila, and niger is kala-til (black sesame) and ramtil. Castor in Kannada is alasi, and niger is ulisi. Ellu is sesame in Tamil and Telugu, in which huchchellu and gurellu stand for niger. That a new crop should be named after existing older ones does not generally suggest great antiquity, and the small niger seed does of course resemble the ancient sesame.

The crop and oilseed

Very poor soils will sustain the niger plant.[125a] It is half a metre tall with pretty yellow flowers and long, wire-like shining black seeds. The crop is cut near the root when ripe, stacked for a week, then exposed to the sun and the seed beaten out, after which the very light chaff is easily blown away. Fertile soils are said to yield plump seeds.[125b]

The seed stores excellently for even a year, and is crushed when needed since the oil is prone to rancidity.[125c] Since the cake is very dark in colour and not easily acceptable as a cattle feed,[125d] it was stated even in 1952 that "telis invariably crush niger seed with small quantities of edible oilseeds, such as groundnut, safflower or sesame"; and further that "niger seed oil and oilcake in this (Hyderabad) state are therefore available only in mixed form."[125d] The seed is also reported to have been used as a binder in the ghani crushing of rape-mustard seeds.[125e]

Niger seed oil is a sweet edible oil with a nutty flavour and pale yellow colour, usually eaten unrefined. The expeller oilcake has 37 per cent protein, 14 per cent fibre, and 2 per cent each of P_2O_5 and CaO, and is valued as a cattlefeed and fertiliser.[115b]

A 8. SAFFLOWER

History of use

The grave cloths of many ancient Egyptian mummies were dyed with safflower dye, and fragments of the plant and seeds have been found in the tombs as well.[85h,86] Knowledge of the dye, or perhaps of its use, would appear to be recent in India, since mention in ancient Sanskrit texts is always of the kusumbha seed as a purgative, or as a source of oil or medicated oil.[84f] Such a reference first occurs in early Buddhist canon of about 400 BC,[80d] and in the *Arthasāstra* of Kautilya in 300 BC.[34d] This name survives as kusuma in southern India today, whereas karadi is the more general term.

Origin and Indian types

The *Carthamus tinctorius* of the present could have originated from

two ancestors. *C. lunatus* is found wild in Kashmir at about 2000 m, while *C. oxycantha* also grows wild in Uttar Pradesh, Punjab and the mountainous areas of Pakistan and Baluchistan, the latter centre being favoured.[115c] *C. oxycantha* is a very spiny plant, and a troublesome weed in areas where it occurs wild.

Two distinct types of *C. tinctorius* were developed in India, one particularly valued for its dye and the other for its oilseed.[84f,84h] Till a couple of decades ago, as many as 60 races falling into these two broad types were cultivated in the country.[115c] The dye-bearing plant was not very spiny, and carried orange or yellow flowers tinged with scarlet. These were widely grown about a century ago in Bengal, Uttar Pradesh and Punjab, and were called by various names such as bhuiti in Patna, bodki in western Madhya Pradesh, murilia in Aramgarh and bodi on the Deccan plateau.[84f,85h,87b]

The oil-bearing safflower type was a very spiny plant with yellow flowers, grown for its oil in Madhya Pradesh, Maharashtra and Karnataka. This was called kutela in Patna, kati in Berar, and karadi, sadhi or kusuma in south India.[84f,85h] Safflower seeds used for crushing oil are of two kinds. The majority are glossy and white, rather like sunflower seeds in shape and size, and others are of the same shape, but mottled brown-grey in colour.[84f]

The historic safflower dye industry

Safflower dye was in great demand in Europe a century ago. Its main constituent is the scarlet carthamine. In 1874-75 export of some 516 tonnes of the compressed material, then worth Rs. 65,100, was recorded.[85h] By the end of the century exports had fallen to a third following the development of aniline dyes, though the demand within India for dyeing sacred garments, and in confectionery and cosmetics, kept the industry going. Watt remarked in 1908 that "but for the local markets, the dye might by now have disappeared completely from India as has the madder from Europe."[85h] This has indeed now more or less come to pass.

The florets of the less spinose types of safflower were collected on alternate days before they opened, and dried in the shade. Washing them with water removed the worthless soluble yellow surface colour, constituting about a third of the total dye content.[127A] Once the washings were clear, the wet flowers were partly dried and pressed together to yield small cakes which constituted the article of commerce.[85h] Alternatively the shade-dried florets were dressed with a little sesame oil, fully dried in the sun, powdered, and sifted through fine sieves.[87] The dye had also a reputation as a purgative.[115c]

Other safflower products

Tender safflower shoots are eaten as a green vegetable.[85h] The seeds, obtained by the usual threshing and winnowing procedures, are eaten after

roasting, and used extensively for crushing. Safflower cake is valued as both cattlefeed and manure.

3.2 Newer Oilseed Introductions (Group B)

While the eight oilseeds that have just been considered made their appearance in India at various points of historical time, they can all be regarded as ancient. The process of introduction of oilseeds has continued, and four have gained importance only during the present century. It is these oilseeds, designated Group B, that will now be considered.

Production of these oilseeds in India in 1983-84, and of the oils obtained from them, is shown in the lower half of Table 1.

Table 1. Availability of oilseeds of Group A (Historical oilseeds) and Group B (Newer oilseeds introductions) in India during 1983-84[100]

	Oilseeds th. tonnes	Oil th. tonnes
Group A. Historical oilseeds		
A1. Sesame	618	194
A2. Cottonseed	2,600	170
A3. Rape-mustard	2,566	820
A4. Copra	360	227
A5. Linseed	440	132
A6. Castor	407	145
A7. Niger	175	45
A8. Safflower	469	173
Group B. Newer oilseed introductions		
B1. Groundnut (as kernels)	5,099	1,703
B2. Soybean	412	58
B3. Sunflower	272	102
B4. Oilpalm	Small	Small

B 1. GROUNDNUT

Origin

The groundnut has been found in ancient Peruvian tombs dated at 3000 to 2000 BC,[126a] but may be of even older origin.[124a] The current wild *Arachis monticola*, a diploid, may have given rise to a wild tetraploid, no longer current, from which the cultivated tetraploid *Arachis hypogaea* is believed to have arisen long ago, probably in the Bolivian region of South America.[124b] From here the groundnut fanned out to secondary centres of diversity, where arose the two subspecies, namely *hypogaea* and *fastigiata*. The first of these is characterised by a lack of floral axes on the main axis, and by alternate pairs of vegetable and floral axes along the lateral branches, while the other subspecies carries floral axes along the main axis, and has continuous runs of floral axes along the lateral branches.[124b] Subsequent movement over a wide area of South America gave rise to

two varieties within each subspecies, the four resulting types corresponding broadly to those now called Virginia, Peruvian Runner, Valencia and Spanish respectively.[134b] Older classifications and names have thus been replaced.[128a] Though bunch types usually yield smaller pods and nuts than do runners, the number of nuts in the pod and the degree of constrictions between nuts can vary in both plant types. In both, the flowers are small and yellow, and are borne on long stalks which curl downwards to bury themselves in the ground, where the pods mature.[129] The name groundnut is so appropriate that it has passed into many languages.

Movement to India

There is some speculation, though the evidence is extremely slender, that the groundnut had reached Africa before Columbus.[130] The early Portuguese navigators appeared to have taken the large Brazilian pod forms to Africa, while the Spaniards, who then ruled the Philippines, carried the small Peruvian forms to the Philippines, China and eventually to India. The entry into China is dated about 1529,[85f] and that into India could also have occurred about that time either from Manila or China through eastern coastal ports. However, on the basis of plant types, independent entry into India from Africa through the western seaboard also seems likely.[92b] The first report of groundnut cultivation in India is only dated 1800 AD.[85f]

One argument for entry from the Philippines was the name Manila-kottai used for the groundnut in south India. However this would appear to be a misreading of the Tamil compound word mannal-velli-kottai, which means simply earth-field-nut.[131] Another name it acquired in the heyday of groundnut processing in the eighties of the nineteenth century was cheetu-kilichchan-kottai, the nut that resulted in the tearing-up of promissory notes given against loans, which were paid back by farmers from the substantial profits of raising groundnuts.[87b]

When the groundnut crop in south India failed rather dramatically at the end of the last century, Parry and Co. introduced in 1894 the so-called Mauritius variety from Mozambique, which caused a dramatic come-back of the crop in the area round Pondicherry. In 1901-02, the same variety was taken from Pondicherry to Bombay state, which also brought in Spanish and Virginia varieties from the U.S.A., and Small Japan and Big Japan from that country.[126a] Thus considerable diversity of type was established quite early in the development of the groundnut crop in India.

Pioneers in groundnut development

By 1850, some 1,000 ha were under groundnut in the Madras Presidency.[85f] This doubled in the next decade, and by 1895, 70,000 ha had been sown to groundnut mostly in the South Arcot district of Madras.[132;133a] Adjacent was situated the French settlement and port of Pondicherry, and Watt reports: "The groundnut trade between Pondicherry and France is in full swing, and has been so since the month of

February (1884)....The groundnut trade is the most important in the chief town of the French Settlements in India....It is surprising how the South Arcot district can produce such an immense quantity of nuts."[84g]

Govindaiyer (1851 to 1905) of Valavanur (Plate 6) played a significant part in this development.[131] A Calcutta businessman, Sulaiman Salaji, whom he had met, asked the 18-year-old to procure for him 100 casks of groundnut oil to be sent to Burma for use as an edible oil. Trekking through hundreds of villages, he collected groundnuts, got them crushed in village chekkus (as ghanis are called in South India) and had wooden casks made in Cochin in which to despatch the oil. An abiding interest in groundnuts had been created. Noting the poor yields of the three-seeded erect varieties then grown as a single annual crop of 140 days' duration from September to December, he popularised the raising of two crops a year. When groundnut production reached 30,000 tonnes a year, he encouraged people to put up ghanis in the village. In 1878, famine descended, and Govindaiyer countered it by introducing a runner variety of groundnut which rapidly became accepted in the district. By 1900, as many as 1,000 chekkus were operating in Valvanur village alone, and the noise was so great that people had difficulty sleeping at night.[131] As much as 50,000 tonnes of nuts were processed annually, implying a daily capacity of about 160 kg for each ghani; this is an extremely high figure compared to the 35 kg average that now prevails (Section 7.2). The very large ghanis of south India may well have had their origin in the surfeit of raw material of that time.

In 1893, Watt could write that groundnut oil was a commodity scarcely known to the public.[84g] Govindaiyer played a dynamic role in popularising the use of the oil, and resisted the export of nuts from India.[131] After his death in 1905, several European firms entered the trading field, and the imposition of tariffs on imported oil in their countries led to the transfer of groundnuts from India on a large scale. Govindaiyer was a man of great integrity, and of simple personal habits and attire, greatly respected by his staff, his business associates and his European friends. At his death at the age of 54 of a diabetic carbuncle, only 20 per cent of his assets were left to his son; half went to his relatives, friends, servants and destitutes, and the remaining 30 per cent to various charities.[131]

His son, G. Vaidyanatha Iyer, continued the tradition.[131] Machine decorticators for groundnuts, first introduced by the firm of Ralli Bros. in Pondicherry in 1905, were set up by him in Valavanur, and 10 hand screw presses were installed in 1908 soon after these had been introduced into India. Later, four Krupp expellers from Germany were set up in Pondicherry in 1919, and were run by Robert, the son of Henry Gaeble, a partner of Vaidyanatha Iyer and the Mayor of Pondicherry between 1900 and 1920. These expellers were in use till 1943. A unit for refining groundnut oil using hot slaked lime, followed by water washing and steam deodourisation, was set up to supply refined oil to French troops. The calcium soaps obtained were also exported for use in grease manufacture.[131]

Another somewhat later pioneer of groundnuts, in the Saurashtra region of Gujarat, was Maharaja Bhagvatsinhji (Plate 7) of Gondal.[134] He pioneered the growing of groundnuts in his own dominion, and Gondal was the first market where the nuts were popularised. At first, since groundnut oil was strange and not acceptable, it was crushed along with sesame, which was then the major source of domestic oil. This was in camel-drawn village ghanis made of babul wood, the cake being offered to the crusher as payment. The oil was clarified using a wild form of okra (*bhendi*). The first mill exclusively for crushing groundnuts was Noor Oil Mills, set up by Noor Ali Zhaveri with German (presumably Krupp) refining equipment.[134]

Groundnut development in India

The triumphant growth of groundnuts till 1895, when 140,000 ha were under the crop, was rudely interrupted by the advent of disease. Production dropped to half in 1897, and to a third the next year.[85i,133] A new variety of groundnut was then introduced from Mozambique, and by 1902, the total 1895 area had been restored even in the single district of South Arcot in Madras. This variety, subsequently named Coromandel, has since dominated the production of groundnuts all over India. In 1901-02, the Bombay Department of Agriculture brought in Coromandel from Pondicherry, Spanish and Virginia from America, and Small and Bold Japan from Japan, which rapidly established themselves.[100a]

In 1910, groundnut production was 250,000 tonnes, in 1930 1.5 million tonnes, in 1945 3.3 million tonnes and, in 1983, 7 million tonnes. The crop spread from Madras to Gujarat, and gradually to a wide swathe of states all the way down to the south-west of India. The groundnut today constitutes about two-thirds the total Indian production of all oilseeds (Section 12.5). Traditional growing during the rainy or kharif season has diversified to a substantial rabi or winter crop.[100]

Varieties have also diversified, as illustrated by the following crop introductions and types in different areas of the country over the years:[78c]

1905 Special Improved	Spanish, erect	Bombay, Karnataka
1933 Kopergaon-1	Virginia, semi-runner	Maharashtra
1933 Kopergaon-3	Valencia, erect	Western Maharashtra
1940 TMV-1	Virginia, runner	Tamil Nadu
1940 TMV-2	Spanish, erect	Tamil Nadu, Andhra Pradesh and Karnataka
1967 TMV-7	Spanish group, bold pods	Tamil Nadu
1968 TMV-8	Spanish group, high proportion of three-seeded pods	Tamil Nadu

Of 37 varieties recently introduced, 19 are Spanish bunch, eight Virginia bunch, eight Virginia runner and two Valencia.[78c]

Four main types have traditionally been recognised in the trade.[77] Coromandel is a runner type yielding pods with a sharp beak and pronounced surface veins. The large oval kernels have a light red skin that darkens with age. Bold is a runner variety that resembles Coromandel but has bigger seeds, a thicker shell, and a sharper constriction. Khandesh, also called Peanuts, constitutes an erect type originally called Spanish but now replaced by Virginia erect varieties with small pods, a thin shell, a pronounced constriction and small round kernels covered with a light rose skin. Red Natal is an erect type (all its varieties carry the description red), with round kernels and a dark red skin. In 1941, the groundnut out-turn was made up as percentages of Coromandel 56, Bold 18, Khandesh 22, Red Natal 2 and others 2.[77] At present about half the production constitutes bunch or erect types, and the other half runner types.[78d]

Groundnuts come in pods that constitute 30 per cent of the weight. Decortication is effected by the farmers themselves in some parts of south India like South Arcot, and only the kernels are sold. In other parts, like Arcot and Coimbatore, farmers auction dried pods. Throughout western India also, all transactions are as pods, and decortication is done by oilmillers. Means of doing so will be considered in Section 8.2.

B 2. SOYBEAN

Origin

China is undoubtedly the country of origin of the soybean. An ancient *Materia medica* of 4000 BC by the Emperor Shen Nung, called by his people the Heavenly Farmer, is believed to carry a reference to the soybean.[135] The plant has been called tehouan and ta-teon (grand pea) and by Confucius shu or sou, from which the modern term soy probably descends.[135]

Early experiences in India

Rumphius in 1747 described the plant in Java and the Malayan islands, but it was long confused with the *mung* bean, *Phaseolus aureus*.[135] In 1908 the soybean was described as "comparatively recently introduced into India...acclimatised and even seen as an escape from cultivation ...extensively cultivated though more as a garden than as a field crop...especially prevalent in Eastern Bengal, Assam, the Khasia hills, Manipur, the Naga hills and Burma."[85j] Thorough surveys made in India in 1911 by Hooper and two years later by Woodhouse and Taylor showed extensive cultivation of the soybean on the Himalayan slopes up to a height of 2,000 m all the way from Punjab to the hills of Manipur and Burma.[135] The Hindi names for the bean were bhat, bhatwan, and rum-kurthi, and in Bengal gari-kalay.

A few systematic cultivation trials were made in the first two decades of the century. In Coimbatore in Tamil Nadu, Cecil Wood, the Principal of the Agricultural College, examined soybean cultivation in 1915-16; though he concluded that the crop was a fair one, trials were discontinued.[136,137,138a] Trials at the Pusa farm of the Imperial Agricultural Research Institute during 1917 to 1928 were much more extensive.[135] In the first six years, nine varieties were grown with a seed yield of 1312 kg/ha and a foliage out-turn of 885 kg/ha. Three varieties were singled out for further trials. These were a yellow, late-maturing variety with seeds containing 16.9 per cent oil and 38.3 per cent protein; a chocolate late-maturing seed variety with 18.8 per cent oil and 37.3 per cent protein; and a black, short-duration type with 14.4 per cent seed oil. The average seed yield was 1,342 kg/ha. The soybean crop was considered valuable as a source of green fodder in the November gap between the pulse crop masur *(Lens esculenta)* and the forage crop berseem *(Trifolium alexandrinum)*.[135] However these trials were not followed up, probably for the reasons given later.

Efforts in the thirties

Several factors sparked off renewed interest in the soybean in the thirties.[137] In 1932, the Director of Nutrition Research at the Indian Research Fund Association, Coonoor, Maj. Gen. Sir Robert McCarrison wrote: "I strongly advocated the more generalised use of soyabean in India in my evidence, and in the statement submitted by me, to the Royal Commission on Labour... I would advise you to advocate the use of soyabean milk for infants and young children who cannot obtain a sufficiency of mothers' or cows' or other milk."[135] Another economic reason was that the soybean was seriously competing with the Indian groundnut in world markets.[137] And finally the powerful advocacy of Mahatma Gandhi through articles in his newspaper, *Harijan*, led to enormous popular interest.

In November 1935 he wrote that Narhar Bhave (the father of the spiritual leader-to-be Vinobha Bhave) was living wholly on milk and soyabeans at the age of 61, and in imitation of him, "the inmates of Maganvadi (the ashram) including me have been trying soyabeans for the last few days...soyabeans are a most nutritious diet...dal (should be) omitted altogether, soyabean being themselves a most nutritious dal".[135] Shortly thereafter he described the total ingredients that were used to cook dinner for 98 people, which included 4 lb (1800 g) of soybeans. Describing this in a talk to village workers advocating the kind of diet they should eat, he said: "Milk with soyabeans gives us almost all that we need in the shape of fats and there is no need for ghee at all... It was a full meal...Milk may be omitted for the other meals. Wheat *bhakari* (baked bread), soyabean and chatny should be quite enough." The soybeans were "steam-cooked and served whole because of the unpleasant taste of soya milk.... The ration of beans has been increased for the current week from two

ounces to three per head."[135] Other inmates of the Ashram were less enthusiastic. His English disciple Mirabehn (nee Miss Madeleine Slade) wrote that soybeans disagreed with everybody, including Gandhiji.[139]

Many departments of agriculture took up soybean cultivation at the time. At the Imperial Department of Agriculture, two varieties, Pusa Farm Selections No. 1 and No. 2 were developed for both fodder and seed purposes.[135] In Madras, two varieties from Burma, several from Kuala Lumpur, and a number from other places were tried out for two seasons.[137] These included the black-seeded Kuala Lumpur 30 and Laredo, the chocolate-coloured Lyallpur, and the yellow-seeded Mammoth Yellow. Plants were bushy, branching and trailing, and varied in duration from 80 to over 140 days. Seeds were flat, kidney-shaped or round, of various sizes, and in colour pale yellow, deep yellow, chocolate, black and mottled. In Punjab a chocolate and a yellow variety were reported to have yielded 1,125 to 1,500 kg/ha of leaf, and in Pune leaf yields for a yellow, broad-leafed erect variety and a greenish, narrow-leafed variety were from 1,240 to 1,800 kg/ha.[135] In the Central Provinces and Berar region, Java Black and Wilson Early gave fodder yields better than most greens. All these were experimental trials. Only in Darjeeling and Kalimpong were about 80 ha, and in the neighbouring states of Sikkim, Bhutan and Nepal about 320 ha, actually put under soy in rotation with maize or in rice fallows. This was not for green fodder, but for the seed crop, meant for consumption by local farmers and hill tribes.[135]

The princely state of Baroda took a special interest in soybean cultivation.[136] Mammoth Yellow was acclimatised all over Gujarat, a stout, erect, bushy plant maturing in 90 days, with white flowers, three-seeded pods and straw-yellow seeds carrying 18.6 per cent oil in yields of 1,300 kg/ha. Two fodder varieties from Pune, a greenish-white variety with small green seeds, and a yellowish-white type with even smaller seeds, less branching and less luxuriant vegetation were tested out as fodder crops. No seed collection was possible, since for the best leaf yields the plants had to be cut down when still quite green and even before they flowered. A bakery was set up in Baroda using soybean products (Plate 8), and a tea room serving soy snacks was organised at an exhibition. The Gaekwad (ruler) of Baroda actively supported his Food Survey Officer, F.S. Kale, an enthusiast for the soybean, who published a book on the subject in 1936 which was reprinted the following year.[136]

Despite these countrywide efforts, soybean cultivation in India did not then catch on. Several reasons were advanced for this.[137] The plant could not stand water-stagnation in rice fields and fallows. It was liable to heavy pest infestation. The bean was more difficult to cook than traditional pulses, and its flavour was unacceptable. A review in 1948 stated that at "a very rough estimate" just 1,000 tonnes of soybeans were then being produced in India.[115b]

The seventies: an upsurge

Agricultural planners looking for a crop to occupy black soil areas of high rainfall that were traditionally kept fallow in the rainy season felt that the soybean might fill the bill. A research project of the Indian Council of Agricultural Research, centred at the agricultural univerity at Pantnagar in Uttar Pradesh, provided R and D support. Yellow varieties brought in from America, like Lee, Bragg, Hardee and Davis, were supplemented with local acculturations like Jupiter, Ankur, Gaurav and Durga.[78e] Varieties for specific areas were bred, like Shilajeet for the northern hilly terrain, Co-1 and KHSb-2 for the south, and N-23A and PK-71-21 for the Bihar plains.[78f] Most of these were of 105 to 120 days' duration, yielded between 2,200 and 2,800 kg/ha of seed under experimental cultivation, and were resistant to the yellow mosaic virus. Rhizobial cultures, especially *Rhizobium japonicum*, were manufactured and marketed locally to enable seed to be dressed before planting.

The returns from soybean to the farmer were higher than for other crops like groundnut, sorghum and ragi (*Eleusine coracana*). Support prices, as for major oilseed crops, were first announced by the state governments of Madhya Pradesh and Uttar Pradesh in 1973, and later by the central government, and served as an incentive to farmers. Processing units for soybeans rapidly came up. As a consequence the area under the soybean, which was just 33,700 ha in 1973 rose to 195,000 ha in 1978 and crossed the million mark in 1984.[78f] About 12 per cent of this is in the state of Uttar Pradesh, and the rest is overwhelmingly in Madhya Pradesh. Soybean production in 1984 was 730,000 tonnes, and in 1987 835,000 tonnes.

Market development was facilitated by increasing production. Oil was absorbed by the hydrogenation industries, and defatted flour by antibiotic industries needing a nitrogen source.[140] From 1980, exports of meal from India started in a small way and then expanded to cover practically all the flour produced.[100]

When market expansion occurred, it was suddenly found that black-seeded soybeans had always been raised under the name kali-tur (black dal) in a few hilly areas. These were a carry-over from the earlier attempts to grow soybeans. These black soybeans rapidly descended into the plains to compete with the yellow varieties.[140] They germinated better, were more disease resistant and had higher oil and protein contents than the latter. In 1979, black soy made up over 90 per cent of production. In 1983, about half the total soy production was through black soybeans, but since then the balance has tilted in favour of yellow varieties. Decortication of the tough black shell is difficult, and black specks mar the appearance of the solvent deoiled meal and its acceptance in overseas markets.

B 3. SUNFLOWER

History

***Helianthus annuus*, the sunflower, is now believed to have originated in**

the south-west of North America, on the basis of archaeological finds dating even as far back as 3000 BC of both wild and cultivated forms at several sites.[128a] An earlier attribution to Mexico, and an origin from *H. lenticularis*,[115e] are now considered incorrect. The utility of the unbranched plant over the ornamental, heavily-branched types was recognised very early. The seeds first reached Spain in 1581, and were grown as ornamental plants which then travelled across Europe. Even by 1769 in Bavaria, cultivation for oil is recorded,[128a] and this assumed significance in Russia about 1830. Later systematic breeding there led eventually to varieties of just 73 days' duration, with huge flower heads packed with seeds carrying only 20 per cent shells, and kernels with as much as 73 per cent oil.[141]

Development in India

In the forties, a variety of sunflower called Jupiter was raised in India as a potential source of seed oil, but it did not catch on.[141] The early seventies saw several Russian varieties being brought into the country for acculturation, such as Armaverts, Armaviriski, Peredavik and Cernaianka.[142] These in time gave rise to the Indian types EC 68414, EC 68415, Morden and BSH-1.[78c,78g] Both Morden, which is a 75-day, largely self-fertile variety, and BSH-1, a hybrid which matures in 95 days and yields 1,000 to 1,500 kg of seed per ha, were rapidly adopted by farmers and grown either as a pure or a mixed crop over about 750,000 ha in 1983.[78b]

An initial setback of poor seed-filling was traced to absence in India of the extensive bee activity necessary to achieve full cross-pollination.[78g] Remedial measures included the development of open-pollinated varieties like Surya and Co-1, and growing the bee-attracting niger plant alongside the sunflower. To transfer pollen, human help was also invoked: a circular rub was given with cloth-covered hands to the flowerheads in the morning hours, or else the hands were passed from flower to flower. The depredations of birds, which wreck the entire head, have to be guarded against through scarecrows and noises. Some 200,000 tonnes of seed are annually raised, about half each in Karnataka and Maharashtra states. Even in times of drought, when the groundnut crop has failed, the adjacent sunflower stand has continued to yield,[78h] because the deep tap-root can use subsoil water.

The seed is threshed from the heads either manually or mechanically (see Section 8.2). Processing is by expeller and solvent operation.

B 4. OIL PALM

Origin and early history

Elaeis guineensis, the red oil palm, is indigenous to the West Coast of Africa, flourishing in warm, moist conditions along the coast between 16°N and 12°S latitudes.[143a] In 1446, Portuguese sailors first reaching the Gulf of Guinea found that the oil palm constituted an important item of

food among West Africans. After the colonising of Africa, the Belgian Congo by 1948 had 100,000 ha of cultivated oil palm, and a further 240,000 ha under wild plants. Nigeria had only 8,000 ha of cultivated plantations, the bulk of the palm being raised in small holdings by individual farmers.[143a]

The oil palm started on its travels with the discovery of the New World.[143e] It went to Jamaica before 1688, and then again from Africa to Brazil with the slave trade, plantations being developed at both places. Four trees were taken by the Dutch from Africa to the famous Royal Botanic Gardens at Buitzenborg, now called Bogor. These were fortunately of a superb stable variety, and it was the seed from these and their progeny that was used to establish plantations in south-east Asia. By 1914, Sumatra had 2,600 ha which had risen in 1940 to 75,000 ha, while Malaysia developed by 1940 large holdings of oil palm totalling 260,000 ha.[143a] In India the Madras Agriculture Department in 1930 raised seedlings on various soils at four locations; some 28 years later, Urquhart noted that these were doing excellently at Pilicode (Palacode) in Kerala, where experimental studies still continue.[144a]

The best variety at the time was called deli, a name given to it in Indonesia.[143a] The fruits had a medium-thick shell that constituted 35 per cent of the weight, the bunches were large, and yields of three tonnes of oil per ha were consistently obtained in commercial plantations. Another somewhat unstable variety was called Liscombe, with just 10 per cent shell but rather low fruit yields. The variety called pisifera had just been developed, with no shell, a substantial pericarp and a very small kernel.[143a]

Later history and development

The decision of the newly-independent nation of Malaysia in the sixties to develop the oil palm as a major economic crop led to systematic development of both agricultural and technological expertise.[143a] The pisifera variety, rich in pulp and oil, was crossed with the dura variety with large fruit bunches to yield a new variety called tenera that combined the advantages of both and yielded as much as six tonnes of oil per ha.[143e] Production was found to start about the fifth year and continue for 25 years. Tissue culture techniques were employed to raise plants of uniform and high quality.

Early problems concerned the monoecious nature of the plant, in which male flowers appear first, followed by female.[78i,78j] Water stress favours the production of male flowers, and fruiting is reduced through abortions of female flowers. The introduction of a weevil that achieves full pollination markedly improves fruit formation, and use of two weevils, each of which thrives in a different season, is even more effective.[144] Quick transport of fruit to the factory and instant steam sterilisation reduced the rapid development of free fatty acidity which occurs in the oil through bruising and enzyme activity. Techniques and equipment developed for oil recovery involved fruit stripping after steam sterilisation, expelling in

special twin-screw expellers designed to deal with a fibrous cake, and kernel removal, followed by processing for palm kernel oil. For the deep red palm fruit oil, novel techniques of physical refining by vacuum deacidification were developed, preceded by bleaching. New processes for resolution of palm oil into olein and stearin fractions to meet different end-uses were made operational.

The Indian experience

In 1966, Davidson conducted an enquiry into the prospects of the oil palm in India, and identified 24,000 ha in Kerala (one-third through government and the rest private), 5,000 ha in the Little Andaman islands and 4,000 ha in the Greater Andaman islands as suitable for the purpose.[145] At the Coconut Research Stations at Anakapalle and Ambajipet, various crosses of dura, pisifera and tenera were experimented with and the fruits examined.[146,147,148,149] In the event, dura-tenera crosses were shown to bear fruit with 80 per cent pulp that carried 66 per cent oil, both considerably higher than crosses of dura with pisifera (60 per cent pulp, 50 per cent oil) and of dura with dura (52 per cent pulp, 50 per cent oil).[149]

About 1977, Oil Palm (India) Ltd. was formed as a holding company that has since brought under tenera palm cultivation 3,700 ha in the Anchal highlands of the Quilon district in Kerala. In the Little Andaman islands another 1,200 ha have also been raised under other auspices. While most of the plants have still to reach maturity, a few facts have emerged.[144] Kerala is within the traditional geographical limits of the oil palm, but the rainfall is considerably lower than optimal, and much less evenly distributed. Nevertheless the introduction of the weevil has led to fruit development that promises, in time, to approach that of Malaysia, showing that moisture stress is less important to male-female flowering than proper pollination. The role of irrigation is not yet clear. Probably irrigated areas in India well outside the traditional limits would support the oil palm. The possibilities of developing small holdings which would domesticate the oil palm in the manner of coconut will require an infrastructure for fruit collection and processing without delay. While the present out-turn in Kerala is just about 2,500 tonnes of fruit yielding about 20 per cent oil, when in full development some 30 times this quantity is expected to be produced.

The fruits are cut down using knives attached to long poles, carried to the roadside, and conveyed to the factory in trucks for processing using modern machinery. The possibility of using raw red palm oil without refining, to take advantage of its exceptional content of 600 mg/g of beta-carotene, is being examined.[150] Deficiency of vitamin A is widely prevalent among children in India, with its aftermath of even total blindness.

3.3 Oil-bearing Materials that are Byproducts of Cultivated Crops (Group C)

The third group of oil-bearing materials, designated Group C, are those

derived from crops cultivated in India for other purposes, but are, or could be, exploited as sources of oil. In many instances, this has only become possible in modern times through the development of such techniques as commercial solvent extraction. Most of these materials are not very ancient in India, except for rice which has a hoary lineage.

Table 2 gives a picture of the estimated potential of these nine oil-bearing materials in India.

C 1. RICEBRAN

Origin of rice

There are some 18,000 varieties of rice in the world, and half that number even in India.[151] Even were one to limit oneself to the genus *Oryza*, a clear twenty can be identified. Wild and cultivated forms cross easily, and dispersal occurred in ancient times through the constant and widespread movements of Asian peoples.[152] Thereafter diversity arose from marked climatic changes after the last Ice Age, dispersal of plants to differing altitudes, latitudes and longitudes, and conscious human selection to suit cultural needs.[152]

The genus *Oryza* originated in Gondwanaland, the huge land mass that fragmented some 100 million years ago, and was followed by continental drifts that gave rise to Africa, India and Australia. The evolutionary process in India started with a wild perennial form of grass, *O. rufipogon*, which gave rise to a wild annual, *O. nivara.*[25b] This is the so-called wild rice which is even now found floating on the margins of tanks or in deeply submerged fields in Bengal and Madras. The aquatic wild rice of North America is a totally different species, *Zizania acuatica*. A multiplicity of variations exist: both awned and awnless, and in colour red, white and almost black.[85k] It was *nivara* that gave rise to *O. sativa*,[25b] the major rice species of today, primarily along the foothills of the long Indian Himalayan range, and its radiating arms in South-East Asia and China. Three ecogeographic races, termed *indica*, *japonica* and *javanica*, arose during these migrations as a result of various geographic and human pressures. The *indica* race has a high (25 per cent) amylose content, and cooks to fluffy masses with discrete grains. Low-amylose (15 per cent) *japonica* varieties cook to sticky masses amenable to lifting with chopsticks.[153] *Javanica* rices are of intermediate amylose level, and large in grain size besides.[154] White and red are the usual grain colours.

The archaeological record

Radio-carbon analysis has placed the antiquity of rice found in South-East Asia at 6000 BC.[124] Rice finds in Thailand go back to 5000 to 3500 BC.[130] Rice glumes were found at a site in China dated 3280 BC,[152] and Chinese writings of about 2800 BC mention rice.[155]

Terraced fields are typical of rice cultivation. The discovery of such terraces in an Ice Age site in Kashmir dated about 10,000 BC raises inter-

Table 2. Estimated availability of oil-bearing materials derived as byproducts of cultivated crops (Group C)

Oil-bearing material	Estimated availability th. tonnes	Wt. of seed	Kernel : hull ratio	Oil content %	Oil potential th. tonnes
C1. Ricebran	300	—	—	15	45.0
C2. Tapioca seed	150	1 g	50 : 50	26	37.5
C3. Maize germ	50	—	—	50	25.0
C4. Tobacco seed	80	1 g	Processed whole	38	30.4
C5. Rubber seed	30	3 g	53 : 47	25	7.5
C6. Tung seed	0.5	13-25 g*	69 : 31	62**	0.2
C7. Jute seed	880	1.8 mg, 3.3 mg†	Processed whole	13	10.4
C8. Spent coffee	2	—	—	15	0.03
C9. Tea seed	Not known‡	0.9-1.9 g	30 : 70	19-34	—

*Three sizes between these limits.
**Oil in kernels %.
†For *C. olitorius* and *C. capsularis* respectively.
‡Change of present cultivation practice would be necessary (see Text).

esting possibilities.[156] Both wild and cultivated rices unearthed at Koldiwha in Uttar Pradesh, 300 km east of Patna and close to Allahabad, have been carbon-dated to 5000 BC.[156] Finds of rice grains in other archaeological excavations in various regions of India (see Map) are roughly as follows, all dates being BC:[1g,12a]

West: Lothal 2300, Rangpur 2000, Ahar 1900
North: Mohenjodaro 2000, Atranjikhera 2000
Indo-Gangetic: Chirand 1800, Patna 1800, Hulas 1600
East: Baidipur 1500
Central: Navdatoli 1600, Maheswar 1600, Nevasa 1300
Deccan: Inamgaon 1400, Hallur 1000, Adichanallur 1000

Though Gujarat and Punjab sites show the oldest dates, rice could have originated anywhere along the length of the Himalayan foothills, and established itself wherever it entered a fertile alluvial plain. In south India rice seems to have put in an appearance somewhat later than elsewhere in the country.

Names of rice

The word for rice is similar in old Persian, virinzi, to that in Old Sanskrit, varisi and later vrihi.[83k,156] This suggests that the nomadic Aryans who entered north-west India about 1800 BC may have already known of the grain, but preferred barley as a regular staple, and did not adopt rice till after they had settled down. Even the Tamil term for rice, arisi, which is still in use, seems likely to have stemmed from the Sanskrit word. Following the trade between Europe and south India which started several centuries before the time of Christ, it is this word arisi that yielded the Greek and Latin oryza.

Literary mention

In many cultures, not only in India but elsewhere, the words for food and for rice are synonymous: examples are the aboriginal chaval (still used in colloquial Hindi), the Sanskrit dhanya and the Tamil soru and kulu. The Munda root jom, meaning to eat, is believed to have given rise to chaval, and the word tandula for rice is also believed to have had an aboriginal origin.[80e] The ancient Dravidian word, kuru, stands for boiled rice.

Rice is not mentioned in the earliest *Rigveda* but frequently thereafter. In the *Yajurveda*, five varieties of rice are mentioned, with mahavrihi (large rice) rated highest.[80d] The process continued down the ages. Summer varieties, called graishmuka and shastika, were of very short, 60-day duration.[38b] Some like sastika were "made without flavour by Brahma" and others, like asu, were dark in colour. Rainy-season varieties, varshikà and vrihi, were clearly the common grade. Autumn rice (sarada) gets only occasional mention, most attention being devoted to superior winter rices. One of these was not transplated, gave exceedingly white grains, and was termed hayavana, hayana and haimantika, suggesting a spring variety. It

was permitted in sacrifices,[157] which would imply some antiquity even by 500 AD. This is the aman rice of today in Bengal.[158] Transplanted winter rices, called sali, were highly regarded.[159] Three types of sali are mentioned: rakta or red, kalama which was hard, bright and flavourful, and maha, the prized variety. This was the type served to Yuan Chwang during his stay around 640 AD in the great Buddhist monastery at Nalanda: it had grains "larger than the black bean" and grew only in Magadha in central India.[19b] Panini (200 BC) describes wild rice as nivara, a term adopted botanically. No less than 26 varieties of rice are listed by name, size, shape, colour and fragrance in the *Krishi-sukti* of Kasyapa, which is placed somewhere between the fifth and the tenth centuries AD.[38] Abul Fazl, the chronicler of the Emperor Akbar, describes in 1590 AD nine types of rice that could be bought in Delhi, ranging five-fold in price from 100 to 20 copper dams per maund (now fixed at 37.26 kg).[160]

South Indian literature, which goes back only to about 200 BC, mentions mountain rice, red rice and white rice, and parched, beaten and parboiled forms of rice.[161] Rice was exported from south India even in the sixth century BC.[80e]

Rice milling

The horny, siliceous outer hull of paddy was commonly detached through pounding in a mortar by women, followed by winnowing to separate hulls, bran, broken rice and whole rice. An old Tamil tale of about 200 AD[162] describes "the white cooked food prepared out of the rice obtained from paddy by hand pounding, which had worn away the iron ring at the end of the thick black wooden pestle", an implement still in use today. A third of the paddy now produced is still hand pounded, and the bran is used locally as a cattlefeed.

Foot pounding is done in a dhenki, a pounder mounted at the end of a plank. This is pivoted in the middle, raised by pressing the other end down with the foot, and then released with considerable force. A second woman builds up the paddy held in a wooden mortar into a little mound to await the next rhythmic descent of the pestle. The dhenki has even been deified: it is considered as a vahana or vehicle of the sage Nāradā, and is worshipped on solemn occasions such as a marriage or sacred thread initiation ceremony.[163]

Rice hullers consist of two revolving cylinders of stone, one carrying a steel blade and the other grooved to receive grain. Thereafter the grain may pass to a similar fine-polishing arrangement. Shellers are emery or cement-coated iron discs, one stationary and one moving, between which the rice is abraded, followed by sieving to separate bran. Use of rubber-coated shellers yields bran of better quality. Parboiled paddy, which means its partial boiling with water, or exposure to steam, followed by drying, yields on subsequent sheller-milling a bran of high quality for solvent extraction, with 25 per cent oil against the 15 per cent in sheller bran and the 8 to 9 per cent of huller bran.

Bran upgrading will be considered in Chapter 8.

C 2. TAPIOCA SEED

Origin

Wild species of *Manihot* have been found in both South and Central America. Though prehistoric remains have been discovered in coastal Peru, the scene of domestication is thought to be either Brazil or Venezuela, from where the species moved into Central America. The Incas used the tubers as food.[130]

It was the intrepid Portuguese who carried the tapioca from Brazil to Africa, from where it probably reached India. It is not mentioned by Linschoten (1598) in his meticulous listing of the tubers of India. Voight states that it was brought in from South America to the Horticultural Station at Serampore near Calcutta in 1794, but failed to flower.[84h] However, barely a half-century later, the plant is reported as abundant in various places. Jenkins stated that though never seen wild, it was plentiful in Assam under the name hemalu, since the leaves resemble the simul (*Bombax ceiba*) and the tubers (alu) are edible. The latter could achieve a weight of up to 20 kg, and were reported to be eaten even uncooked. The plant was also abundant in Travancore, and in April 1882 it was stated: "As the price of rice has risen of late years, tapioca has become the more essential as an article of food . . . well boiled, it is eaten with fish curry." And again: "Within the last few years the cultivation of tapioca has so extended that it has become a staple article of food."[84h] Thereby hangs a royal tale.

Establishment in Kerala, and types grown

About a century ago Kerala was in the grip of famine following failure of the rice crop. Distressed at this, the ruler of Travancore between 1880 and 1885, Vaishakam Thirunal, is believed to have examined several existing crops as future staple safeguards, such as the tapioca, the sweet potato and the bread fruit.[164] The tapioca won hands down, and the ruler personally propagated it throughout his kingdom with missionary zeal. It yields 9,000 kg or some 8,000 calories to a ha, four times what rice can do.[133b] It can be grown behind every home, and left in the ground till needed. Some 300,000 ha of an undulating strip of land lying between the sea and the littoral is now covered with an evergreen crop of five-leaved tapioca.[115d]

The tapioca is now termed *Manihot esculenta*. Earlier it was classified as *M. utilissima*, but this is now applied to the showy ornamental form with variegated green and yellow leaves. A related species. *M. glaziovii*, which was raised about a century ago in the Coorg hills of the Western Ghats of south India for its rubber-forming latex, also yielded large starchy tubers.[115d] Moreover the leaves, flowers, fruits and root bark were all reported to carry cyanogenic compounds. This species has been crossed

with *M. esculenta* to achieve vigour, high tuber yield, spread of tubers and drought resistance.[115d] Such hybridisation has further confused the distinction once made between varieties yielding sweet tubers that could be eaten uncooked or without special precautions, and bitter tubers containing hydrocyanic acid, that needed to be leached with boiling water before conversion to edible dried chips or flour.

As many as 75 types have been recognised in Kerala, all with 2n=36 chromosomes.[115d] It is now believed that a sweet variety in one location can be bitter elsewhere, and *vice versa*, depending on the fertility and moisture status of the soil.[165a] In general, plants of seven to eight months' duration are used for edible purposes, and those growing over 10 to 12 months for industrial starch manufacture, the proportions of the tubers thus used being about 60 : 40. Varieties with bitter potential are chosen for the latter purpose, and, even when raised on untended forest lands, are left alone by grazing animals. Young tapioca leaves, which carry 21 to 36 per cent protein in their dry matter, are relished as a chutney in Kerala, but are thoroughly steeped in water before use, since the hydrogen cyanide content can be as high as 90 mg/100 g.[115d]

Tapioca seed

It was considered axiomatic that only non-branching and non-flowering varieties of the tapioca plant would bear a high tuber yield. However there is a view to the contrary. In one experimental study, where seed capsules were allowed to set, the tuber yield was found to be 25 kg/ha against a normal average figure of 17.5 kg.[166] Seed setting was 75 per cent, and a plant bore on an average 130 to 170 capsules each carrying three seeds. The seed yield per ha was estimated at 400 kg, which would mean a potential from the tapioca now grown of 150,000 tonnes of seed or 40,000 tonnes of oil.

C 3. MAIZE GERM

Origin

On the authority of de Candolle, New Granada in South America had long been accepted as the place of origin of maize. Dramatic evidence from archaeological excavations in 1948 in the Tehuacan 'Bat' rock caves in Mexico laid older speculation at rest, because here were found corn pods 7,000 years old, that were just 2 cm long and carried 50 to 70 kernels.[114b] Thereafter up to 400 BC there was a continuous evolution in cob size and grain productivity, showing that maize had evolved in Mexico. Indeed the staple food of the Aztecs took the form of large baked maize tortillas, 30 cms in diameter.[167a]

How did even the early, tiny corn cob originate? It was earlier believed that the ancestor was a wild corn, now long extinct.[168] This was a pod corn, in which each small seed is fully covered by a case. If this head is popped as a whole using heat, the burst seeds can be collected and

used. Modern corn was believed to have resulted when pod corn crossed with the common wild grass known as tripsacum, which is itself descended from another grass, teosinte, found wild even now in Guatemala and Mexico. Today there is strong evidence that teosinte and not tripsacum was the direct ancestor of modern maize, the crucial step having been a single mutation that converts the hard fruit cases into soft, husk-like glumes from which the kernels can be threshed with ease.[169] The 'Bat' cave remains represent stages in the transition from teosinte to maize as a result of human selection.

Maize in India

It is interesting that maize was first called Turkey corn in Europe.[130] Many names for maize in India are also derived from the word makka or makkai, suggestive of holy Mecca and a Middle Eastern entry of corn into India. However, since sorghum is called Durrahi-i-Makka or Gandum-i-Makka,[84l] the term makka may only connote the resemblance of maize to sorghum which is quite striking, except for grain size. In fact the expression large sorghum is a frequent one among names for the maize, such as bara-jouar in Bengali.[115e] The other common name bhutta may derive from the identical Pali word that means to eat. Alternatively it may stem from the Sanskrit bhuta, a seed or rosary bean, which is frequently given to various items introduced into India.[84l] The Sanskrit dictionary lists three names for maize, which are sasyam (=any grain), stamba-kari (=cluster grain) and sasya-visesha (=remarkable grain),[170] all of which are simply descriptive terms.

Early writers on India are silent on the subject of maize: Abul Fazl's *Ain-i-Akbari* (1590), Linschoten's *Voyage to the East Indies* (1598) and Rumphius' *Batteca* (1750).[84l] Yet in 1819, Buchanan-Hamilton noted that it was a common food in Nepal and a food of the poor in Kangra, and two decades later, Graham (1839) reported that maize was commonly cultivated in western India.[84l] It seem possible that for perhaps two centuries the plant was only grown experimentally, but once it became acclimatised and its food potential was realised, maize cultivation spread rapidly to its present areas in Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh and Punjab.[115e] American maize seeds brought into India for cultivation about 1830 did exceedingly well in Uttar Pradesh and Bengal, in particular the two varieties Prolific and White Flint.[98a] Preferred forms are those whose pods are decidedly sweet for eating when still unripe, and which give a mature flour, which is also sweet, for making chapatis. Very hard, smooth, shining flint corn is also popular for its flour (makki) in India. Other varieties like dent corn, with a pit at the top of the grain, have also been introduced.

While introduction of maize into India in the early sixteenth century AD by the Portuguese has been postulated, there are some intriguing findings. Edgar Anderson found small-eared varieties, similar to those once grown in Mexico, being raised in the hills of Assam by Naga headhun-

ters.[126b] Japanese scientists who examined varieties growing in Sikkim stated that one was an Iranian type with a morphological resemblance to sorghum, and another an Aegean type which had developed from the Iranian type without hybridisation.[111b] Dhawan showed that two of the Sikkim varieties are strikingly primitive,[171] and Thapa found the same also true for the forms being used by the Lepchas of Tibet.[172] This maize was also studied by Mangelsdorf who pronounced it "a derivative of the Mexican popcorn race Papomero Toloqueno."[173] Assuming these to be remnants of very early introductions, when did this happen, and how?

A potsherd found at an archaeological site dated 1435 AD at Kaundinyapur (Madhya Pradesh) bore an impression on the clay strikingly like that of a maize cob.[115e] Pollen grains from sites in the Kashmir Valley of a very early date have been identified as those of maize.[173] Finally, several sculptural representations in the twelfth century Somnathpura temple not far from Mysore city show goddesses holding in their left hands something which looks very much like a corn cob, and rather too long and deeply indented to be lotus buds. Mangelsdorf dismisses the evidence stating: "Perhaps there has been a pre-Columban trans-Pacific migration of culture and maize has been involved in it," but that there is no tangible evidence of it whatsoever.[173] Yet there are several other plant species, notably pulses and gourds, that undoubtedly originated in South America, but which India has grown and recorded a millennium before the Christian era began.

Mention in Sanskrit literature is undoubtedly late. The first reference to makka is in the *Raghunātha Ganēsa Navahastā* and the *Lolimbarāja*,[174] both in the last quarter of the sixteenth century AD, and about a century later in the celebrated *Bhōjana Kuthuhāla* written by Raghunātha.[175]

Maize germs

The germ of the maize kernel makes up from 5 to 10 per cent;[143b] and it varies in size, being large in the types specially bred for a high yield of oil.[78k] The oil in the germ develops rapidly in the third and fourth weeks of kernel development, and can carry between 30 and 50 per cent oil. In fact high-oil maize varieties giving as much as 16 per cent oil on the kernel as a whole have been developed in Illinois in the U.S.A., but usual figures are from 3 to 7 per cent.[143b] Indian hybrid maize (1964) carried an average of 9.7 per cent germ with 35 per cent oil on average.[175A]

The germs are isolated during wet milling processes for the production of maize starch. Following steeping and disintegration of the grain, the loosened germ is isolated by floatation on a thin slurry of starch, followed by washing and drying. The dried germs are exploited for oil. Poor drying causes high free acidity development.[175A]

C 4. TOBACCO SEED

Origins and dispersal to Europe

The Aztecs of Mexico, in their long rule from 1300 to 1519 AD, smok-

Fig. 7. Tobacco: plant, flowers and seed (Courtesy: Khadi and Village Industries Commission. Bombay)

ed tobacco in a hollow reed, and later in their history also used elbow-shaped pipes, perhaps in ceremonial functions.[167] The genus *Nicotiana* has innumerable species, variously numbered from 35 to 60.[115f,128b] However only two of these are used to make tobacco and hence widely cultivated. *N. tabacum* itself has six varieties listed, originating from Mexico or Brazil.[85l] The variety from the Orinoco valley was taken to Virginia by early English colonists, and has given rise to highly valued cultivars. The variety *brasiliensis* went from Brazil to Europe for snuff-manufacture, and the Mexican variety, later termed *havenensis*, to Cuba to spawn its famous cigars. *N. rustica*, Mexican in origin, was sent about 1560 AD to Catherine de Medici of France by Jean Nicot, the French ambassador in Portugal, who immortalised the genus with his name. This was also the variety that Thomas Hariot first took to England, and which Walter Raleigh and Francis Drake popularised.[85l]

Entry into India

Rustica was also the species that was first cultivated in India for export to Europe,[115f] and it seems to have entered India from several directions. According to Dymock (1890), both the *Dara Shikohi* (which are the annals of the prince Dara Shikoh, eldest son of Shah Jahan) and the *Masir-i-Rahimi* state that the plant was brought to south India by Portuguese traders in 1508 AD.[85l,178] A century later, in 1605, Sebastian Manrique notes the entry of the tobacco plant into Surat, the major port of the western seaboard at the time.[176a] In 1618, William Methwold, an agent of the East India Company posted in the southern kingdom of Golkonda, noted in that area a "store of tobacco . . . much of it exported to Mocha and Arakan, and not a little smoked among themselves. It is but weak, yet sure more care in curing and making it up would help that fault; they only dry the leaves and use it so, without further sophistication."[176a] Even earlier, in October 1613, William Biddulph, another employee of 'John Company' in Surat, mentions widespread tobacco cultivation across the country.[176a]

The Emperor Akbar died in 1605, and yet had an encounter with the weed.[85l] Asad Beg, one of his officers, found some tobacco at Bijapur about 1605 and "never having seen the like in India I brought some with me and prepared a handsome pipe of jewel work". This he presented to the Emperor who said: "Truly we must not reject a thing that has been adopted by the wise men of other nations merely because we cannot find it in our books; or how shall we progress?" His physicians however prevailed, and "His Majesty...did not adopt it." But Asad Beg relates how "the merchants began to sell it, so the habit of smoking spread rapidly": so quickly in fact that Emperor Jahangir, who succeeded Akbar, took alarm and forbade its use.

In 1680 Thomas Bowrey, a seaman who spent 19 years on ships along the coasts of India, stated that tobacco was an admirable herb, much in use by all the natives of India.[85l] It was smoked or chewed after mixing either with ganja, the pressed tender flowers and leaves of cannabinus, or with bhang, the old leaves and seed vessels of the same plant. Even earlier, in 1614, a traveller in India named Floris made a sketch from life of a Hindu woman of Machilipatnam, on the eastern coast of south India, smoking tobacco.[85l]

Tobacco seed

The broad, coarse leaves of *N. rustica*, forming some 10 per cent of the total tobacco grown in India, are used for chewing, as snuff and in hookahs. To stimulate leaf growth and pungency, the inflorescence is nipped off when it appears, and when, a week later, the suckers appear, these are also pinched away.[85l] Virginia tobacco from *N. tabacum*, the major kind grown, has flowers that are pink or white. These are not nipped, but allowed to grow and set to capsules. In them are fine seeds that look almost like dust, which are obtained by chaffing and winnowing.[177]

C 5. RUBBER SEEDS

Origins

The genus *Hevea* is indigenous to the Para forests of the Amazon Valley in Brazil, Venezuela, Peru, Ecuador and Colombia.[215g] Four wild species grew in the past: *Hevea brasiliensis*, *H. benthamiana*, *H. guianensis* and *H. guianensis* var. *lutea*. Considerable introgressive hydridisation in the past especially between *brasiliensis* and *lutea* seems to be responsible for the enormous variability shown by *H. brasiliensis*, the only variety now commercially cultivated for rubber.[115g]

Raising rubber in India

To quote from Watt: "On 4th June 1873, the Director of the Kew Gardens (London) received from Mr. Markham some hundreds of seeds which had been collected by Mr. James Collins. Of these less than a dozen germinated, and 6 were in that year taken out by Dr. King to Calcutta. These did not succeed well in Calcutta, and it was accordingly arranged that Ceylon should be established as the depot for supplying young plants to the parts of India where Hevea cultivation was thought possible. On June 14th, 1876, 70,000 seeds were received at Kew by Mr. Wickham (who had paid for them at the rate of £ 10 per 1000); 4 per cent germinated. Of these, 1,919 plants were sent to Ceylon in 38 Wardian cases, in charge of a gardener, and 90 per cent reached in excellent condition.... A further supply of 100 plants was taken out to Ceylon from Kew by Mr. J.F. Duthie. Similar consignments were also issued from Kew, amounting in all to upwards of 2,000 plants sent to Ceylon...."[84j] In the meantime Sir D. Brandis in 1873 had recommended that "Kanara, Malabar, Travancore and the Burma coast, from Moulmein downwards offered the desired conditions" for growth of the caoutchouc-yielding species of *Hevea*.[84j]

Seedlings were sent from Ceylon to the Royal Botanic Gardens, Calcutta and thence grown in Bengal, Burma and in the Madras Presidency at the Botanic Gardens on the Nilgiri Hills. In 1882, two trees were reported flourishing at Manatodi, and numerous trees at nearby Nilambur.[84j] In the event the rubber plantations round Calcutta were abandoned, but those established in 1905 at Periyar and Poonoor in Kerala flourished, and have spread to now cover 380,000 ha in the Kottayam and Quilon districts of Kerala, the Kanyakumari district of Tamil Nadu, and coastal Karnataka.[115g] Some 235,000 tonnes of rubber are annually produced in the country.[178a]

Rubber seeds

Each tree bears between 1 and 1.5 kg of fruit capsules and each capsule carries three seeds.[179] It was estimated in 1962 that the 120,000 ha then under rubber in India supported trees that would yield 30,000 tonnes of rubber seed.[179] Another estimate has 11,000 tonnes of seed from Kerala

alone.[180] Collection, ripening, drying and storage were studied under a pilot project of the Khadi and Village Industries Commission in Areplachy in the Punnalur rubber-growing area.[181] Ripening and dropping of the seed coincide with the onset of the monsoon in early June, when sun-drying is difficult. If not dried, wet seed is prone to insect attack, and seed storage also yields oil of high acidity.[181]

Though rubber seeds lying on the ground are eaten by cattle, animals will reject them if furnished as a single feed.[181]

C 6. TUNG SEEDS

History

The true tung tree, *Aleurites fordii*, is native to Northern China, while in Southern China and Cambodia the species *A. montana* grows better.[143c] Tung was found growing wild in Nepal about a century ago, but since the extraordinary properties of its seed oil were not known even to the surrounding inhabitants, the species was presumed to be exotic and not native.[84k]

Tree and fruit

A. fordii grows rapidly, bearing fruit in its third year, and yielding a substantial harvest by the seventh year.[143c] The beautiful blossoms are borne in clusters, and the globular ridged fruits, about 5 cm in diameter, each carry five seeds on an average. In China the fruits are stated to be knocked down, heaped in piles to ferment, and depulped using the hands. In plantations in the U.S.A., the fallen seeds are left on the ground for three to four weeks to desiccate, put into sacks which are thereafter held in the natural forks of the tree for two to three weeks to dry out thoroughly, and then sent to the mills.[143c]

Tung growing in India

Even at the turn of the present century, *A. montana* was raised in India.[115h] In 1918, *A. fordii* was introduced into the Ranchi district of Bihar,[182] and use of the tree as a shade-bearer on tea estates in many hilly parts of India became the vogue.[115h] Plantations of tung were developed in West Bengal and Assam, the area in the former state being 320 ha in the early sixties, with plans to double.[183] The total marketable out-turn of tung seeds at that time in the plantations of West Bengal, Assam and Bihar was estimated at 272 tonnes.[183] Besides this, tung trees are still grown in the tea estates of the Kangra Valley in Himachal Pradesh and Punjab, and in those in Assam. Possibly 500 tonnes of tung seed every year are potentially available.[183]

For at least a decade after 1954, between 50 and 150 tonnes of tung seeds were annually crushed for oil by a single concern in Calcutta, Swaika Oil Mills.[183] High oil prices have deterred users of Indian tung oil, though the annual demand is placed at 4,000 tonnes.[183] The poor marketability of tung cake is an added drawback.

C 7. JUTE SEEDS

Origin of the plant

Two species of *Corchorus* contribute to the jute of commerce. *C. capsularis*, the early-maturing species, constitutes three-quarters of total Indian production, having been raised in 1968 over some 885,000 ha mostly in West Bengal.[184] The leaves contain an alkaloid, capsularin, and are bitter, and the plant is for this reason referred to as tita-pat; as contrasted with leaves of the mitha (or sweet) pat, *C. olitorius*, the other form of commercial jute.[84l] It is now generally accepted that while *olitorius* is an indigenous Indian variety, the *capsularis* form came to India comparatively late from south China or Cambodia.[115l] The extensive use of *olitorius* as a green vegetable, and the familiarity with it shown in early Muslim writings, and then by the British, are all suggestive of at least some antiquity.[84l] So are its various names in Bengal. Kashta is from the Sanskrit kasha, a sheath; pat from patta, the Sanskrit generic term for fibre; and nalita, the dish prepared from the leaf, from the Sanskrit nadika.[84l] The origin of the English word jute, first used by Roxburgh about 1810, is uncertain. It may have come from the Sanskrit juta, a general word for fibre. Waste silk in Bengal is called jhuta-jhut (from the Sanskrit word jhut meaning waste) and the golden bands of waste silk do resemble the long shining-yellow fibres of jute.[84l]

Use in India

The early *capsularis* form, grown before the rice crop and therefore favoured agriculturally despite its lower leaf yields, and the late-maturing *olitorius* form, are both cut close to the ground, and retted by soaking in water for three weeks. The fibres are beaten free with wooden mallets and then twisted into hanks, which are washed and dried.[115l] These fibres are carded, drawn, and twisted into yarn before weaving. Bags of various thicknesses, sizes and weights are the main end-products of jute fibre.[185a]

Till the mid-eighteenth century, jute was made and spun entirely by hand. In 1793 the first 100 tonnes of jute was shipped for opinion to Dundee in Scotland, and further consignments were demanded.[98b] The first Indian spinning mill was set up in 1855 in Rishra, and four years later, a large power-driven factory with 192 looms was established in Baranagar, both near Calcutta. By 1885 there were 20 factories with 6,700 looms, and the next year nearly a million tonnes of jute were exported.[98b] Only with the recent advent of synthetic fibres has the demand for jute from India and Bangladesh declined.

The globular seed pods of *capsularis* yield large seeds, reddish-brown in colour and pyramidal in shape, with a dent on one face. The cylindrical pods of *olitorius* are smaller, and the seeds are grey in colour, small and ill-shaped.[184] The seeds of both species carry two bitter constituents. One is a glucoside corchorin, and the other corchoritin.[115l] Generally, jute leaves are cut down before the seeds set, since delay will cause the

fibre to coarsen. It has been argued that even if just a quarter of the crop could be set aside for seed production, some 80,000 tonnes of seed would become available, to yield in turn 10,000 tonnes of oil.[184]

C 8. SPENT COFFEE GROUNDS

Origins

There are at least seven species of the genus *Coffea* which are believed to be indigenous to different parts of the African continent, like East Africa, Sudan, the Guinea Coast and Mozambique.[84m] The most common commercial plant, *C. arabica*, originated in Ethiopia, where it is called bun or boun. From there it was introduced into Yemen about 1470 AD by a certain Sheikh Shihabuddin Dhabani.[84m] Here it became part of the nighty prayer rituals in Yemenite Sufi circles, through which it was carried to the rest of Arabia and thence to Turkey. The Arab word *kahwah*, from which the modern coffee is derived, actually once referred to the ritual wine which was replaced by the new berry decoction.[84m] In 1511, a crusade was mounted in Mecca to ban the use of coffee as unlawful. The first coffee house was opened in Istanbul (then Constantinople) in 1544. An English merchant acquired the coffee habit while living in Aleppo, and on his return home induced a friend, Rossie, to start a coffee shop in London in 1652.[84m] A century later coffee houses achieved distinction as the meeting places of writers like Samuel Johnson and Oliver Goldsmith.

Coffee in India

Arab traders had introduced coffee drinking into India long before the European arrival. Edward Terry, who was in India between 1616 and 1619, wrote: "Many of the people who are strict in their religion use no wine at all. They use a liquor more healthful than pleasant that they call cohha: a black seed boiled in water, which doth little alter the taste of the water. Notwithstanding, it is very good to help digestion, to quicken the spirits and to cleanse the blood."[94] About 1700, Alexander Hamilton records an invitation from the Nawab of Tattah (Sind) "to take a dish of coffee with him."[186] Writing from India, Tavernier notes that Dutch merchants had followed the Arabs as traders in coffee seeds, then raised only in Arabia and Ethiopia, from such ports as Hormuz and Bassora.[85m]

In fact it was the Arabs who first started to grow coffee in Sri Lanka, even before the Portuguese arrival in 1665.[85m] In 1690 the Dutch began systematic cultivation, which continued even after they had left. The British later started plantations, but leaf disease had by 1884 totally decimated them.[85m]

Coffee was first planted in India in a curious way. In 1720, a Muslim divine called Baba Budan returned from the Haj pilgrimage with seven coffee seeds. These he planted outside his cave dwelling in the hills (that have since been named after him) on the Western Ghats of south India.[115j] The descendants of these plants can still be seen there. Roxhburgh and

Royle saw coffee plants in the Botanic Gardens in Calcutta between 1810 and 1820[84m] but by 1889 attempts to grow coffee in Assam, Bengal and other hilly parts of eastern India had been abandoned.[115j] In the south, various Britishers, starting with Bevan in 1822 and Cannon and Cockburn in 1830, raised plantations on the southern hill ranges, which by 1885 covered 150,000 ha.[84m]

C. arabica, the Ethiopian species, is the major type grown, constituting about two-thirds of all Indian coffee. The rest consists of *C. robusta*, a hardy, vigorous plant native to the Congo which yields berries with a high caffeine content (1.5 to 2.5 per cent) and is the preferred species at lower elevations.[185b]

Source of coffee oil

The berries of the coffee plant are wet or dry processed to remove pulp, and the kernels are roasted, ground and blended. Coffee beans and powder carry about 13 per cent of fat,[185b] and in making instant coffee by extraction with hot water, the brew is freed of gums and oil as it passes for concentration through a series of extractors.[187] The spent grounds that are dried in the sun retain this fat, and are thus amenable to commercial extraction. The 2,500 tonnes (dry basis) of grounds estimated to be available could yield 250 to 400 tonnes of oil.[188]

C 9. TEA SEEDS

History of the tea plant

Watt, a pioneer tea planter himself, believed that the Indian state of Manipur, and the adjacent Indo-Burman and Chinese hilly region, are the true homes of the tea plant. Tea exists in Manipur in great profusion as a forest tree, and in certain wooded glades of Assam and Cachar in a form that is either wild, or an escape from early cultivation.[84n] There are 45 species of the genus *Thea* (earlier called *Camellia*), of which *T. sinensis* is the chief tea-producing variety; three subspecies *assamica*, *sinensis* and *cambodia* are recognised according to place or origin.[116k] The Assamese variety is tall and quick-growing, with large leaves that may be either of dark or light colour (called Manipuri and Assam respectively). The Chinese subspecies is smaller and slower-growing, and carries small, leathery, dark green leaves. These two subspecies, and the third one *cambodia*, hybridise readily and all commercial tea leaves represent various degrees of such hybridisation.[116k] While in India the *assamica* leaf characteristics are overwhelmingly favoured for subsequent fermentation to black tea, the Kangra Valley in Punjab does grow a small quantity of the *sinensis* subspecies, from the leaves of which unfermented green tea is made, mostly for export.[98c]

Use of tea

Chinese literature of 2700 BC is reported to refer to the tea plant, the

leaves of which were probably eaten as a vegetable.[84n] By the fourth century AD, the brew is referred to in China, and by the eighth century, the Tang dynasty had even clapped a tax on tea. Till recently, the people of Manipur and upper Burma buried the leaves in the ground to achieve fermentation, and then packed them in bamboo tubes for sale all over the area as a raw material for cooking.[84n]

The Buddhist traveller to India during 671 to 695 AD, I-tsing, mentions the tea brew, and it occurs once again in the hymns of Milarepa, a Buddhist saint (1050 to 1135 AD).[174] Earlier it was the semi-medicinal use of tea that seems to have prevailed in India. The traveller Mandelslo (1662) is quite explicit:[85n] "At our ordinary meetings every day we took only thay (tea), which is commonly used all over the Indies (India), not only amongst those of the country but also among the Dutch and the English who take it as a drug. The Persians instead of thay drink their kahwa (coffee)." In his *Voyage to Surat* (1689), Ovington states that tea was taken by the banias (traders) without sugar, or mixed with a small quantity of conserved lemons, and that tea with added spices was used against headache, gravel and gripe.[85n]

Tea planting in India

When the tea trade from China to Great Britain was in difficulty early in the nineteenth century, tea plantations were sought to be raised in India about 1834 using material imported from China.[98h] Tea had already been found between 1821 and 1826 growing wild in Assam, but this was considered a degraded form, unsuitable for commercial plantation. What turned the scales was the offer in 1841 of two parcels of tea from Indian plants for sale for the first time in the Calcutta market. One consisted of 30 chests manufactured by Ningroola, the chief of the Singphos tribe of Assam, and the other of 95 chests produced in the Government tea plantations, and both were enthusiastically received.[85n] Thereafter private tea plantations came up with great celerity in Assam, Darjeeling and the Nilgiri hills of south India, all based on the so-called large-leaved wild stock found growing at Makum and Nazira in upper Assam.

Tea seeds

In China, Japan and Cambodia, *Thea sasanqua* is raised specially for seed because of its high oil content.[115k] Some of this variety is also raised in the states of Assam, West Bengal and Himachal Pradesh in India, but seeding does not occur because the top leaves and bud are plucked. This practice is also followed in the other leaf tea plantations, and any seed perchance formed drops to the ground and quickly gets covered by the canopy of tea bushes.[189a] Only in special areas, called a bari, are plants allowed to flower abundantly so as to yield seeds; the quantity raised is just enough to meet seeding demands,[189a] but could conceivably be increased.

3.4 Oilseeds with Characteristic Lipid Associates (Group D)

The oilseeds to be considered in the next few sections are grouped as follows:

Group D: 3.4 Oilseeds with characteristic lipid associates
Group E: 3.5 Oilseeds carrying vegetable hard fats
Group F: 3.6 Oilseeds bearing soap-making oils
Group G: 3.7 Oilseeds with oils of an unusual nature
Group H: 3.8 Oilseeds from shrubs

All of them, with a few exceptions, are trees and plants which are indigenous and have a very ancient history in India. This section provides information on the nature of each tree or plant, and of its flower, fruit, seed and kernel.

Table 3 shows the estimated availability, in various states of India, of some of the more abundant oilseeds that grow on trees.[188A, 188B, 189A, 198A, 199]

D 1. NEEM[84o,85o,115l,183,190]

On one of the amulets or seals found at Mohenjodaro (about 2000 BC) is a representation of the neem tree, while the *Atharvaveda* (c. 1000 BC) mentions the nimba.[34d] *Azadirachta indica* can claim to be truly the national tree of India: either growing wild, or cultivated along roadsides, near temple tanks or around villages, it is a common sight everywhere up to an altitude of about 1000 m. From 15 to 20 m in height, the small, graceful leaves are not shed, since the tree is mostly deciduous except in very dry areas. The flowers, borne in clusters, are small, white and fragrant, yielding as fruit a green ellipsoidal drupe that turns yellow as it ripens. The fruit is shed in abundance, or eaten by birds that drop the seeds. The seed carries one greenish kernel. The fruits that fall are swept together, hand-picked and depulped either using running water, or by covering with soil or ash, leaving aside to desiccate, and then trampling. In South India this depulped seed is sold; elsewhere it is the fresh fruit, or the fruit dried along with its pulp. Seeds from neem trees grown in the neighbourhood of villages were once crushed in village ghanis all over the country and the oil used locally (Section 9.2).

All parts of the neem tree are used in home medicine (Chapter 6).

From Table 3, the spread of the neem tree all over India, and its particular concentration in West Bengal and Uttar Pradesh states, is strikingly in evidence.

D 2. KARANJA[84p,85p,115m,183,190]

The first literary reference to the karanja is in the *Apasthāmba Dharma Sûtra*, of about 500 BC. Karanja (*Pongamia pinnata*) formerly classed as *Pongamia glabra* is termed pongam in the south. It is commonly found wild in the Western Ghats of South India, and grows particularly along river banks and near the tidal forests of sea beaches, or as a shady and handsome avenue tree. Some trees have a short bole but others grow even

Table 3. Estimated availability of some tree-borne oilseeds of India*,**

All figures in tonnes
AA=Abundant
A =Available

State	Neem	Karanja	Kusum	Nahor	Undi	Mahua	Sal	Dhupa (kernel)	Kokum	Khakan-Pilu***	Other oilseeds	
											High avail.	Medium avail.
Andhra Pradesh	11,500	40,000	AA	—	A	6,350	—	—	—	A	Ratanjyoti, 23,000: Palas; Thumba	Maroti
Assam	—	—	AA	6,200†	—	—	172,478	—	—	A	Baheda	Pisa; Maroti; Kamala; Ratanjyoti
Bihar	14,130	46,227	42,000	5,650	—	147,353	3,855,022	—	A	—	Palas	Ratanjyoti
Gujarat	19,697	3,121	A	—	—	15,162	—	—	—	31,488		Ratanjyoti
Haryana-Punjab	11,287	—	—	—	—	—	—	—	—	A		Kamala: Ratanjyoti
Karnataka	18,804	598	AA	A	542	1,896	—	5,000	650	A	Palas; Tamarind 20,000	Pisa; Maroti; Kamala; Ratanjyoti
Kerala	—	A	—	2,700	7,400	30,000	—	7,300	A	—	Maroti 2,000; Baheda 70,000; Tamarind 2,000	Pisa
Madhya Pradesh	2,075	379	2,200	—	—	41,260	1,140,000	—	—	A	Palas 350	

Maharashtra	26,397	4,211	A	—	1,000	100,000‡	—	A	A	—	Pisa 300; Palas	Maroti; Ratanjyoti
Orissa	1,000	3,000	AA	—	1,600	10,000	1,000,000	A	A	—	Palas	Pisa; Kamala; Ratanjyoti
Rajasthan	32,000	350	—	—	—	3,500	—	—	A	12,500	Ratanjyoti 1,000; Thumba 23,000	Kamala
Tamil Nadu	37,000	1,920	A	—	725	5,000	—	—	—	A	Palas	Pisa; Maroti; Ratanjyoti
Uttar Pradesh	210,110	A	A	735	—	247,578	—	—	A	18	Palas	Kamala; Ratanjyoti
West Bengal	230,000	6,000	AA	A	200	6,500	4,000	—	A	A		Kamala; Ratanjyoti
	418,000	111,000	44,000+	9,085	11,467	519,650	6,171,500	12,300	3,000	50,000++		

*V. Lakshmikanthan, Ref. 188A.
**V. Lakshmikanthan, Ref. 188B.
***C.L. Sharma, Ref. 198A.
†V. Lakshmikanthan, Ref. 198A.
‡Harish Sethi, Ref. 189b.
+A figure of 90,000 tonnes is given in Ref. 189A.
++K.D. Hervatte, Ref. 199.

18 m tall. It is a fastgrowing tree, tolerant of drought and salinity, and the leaves are used as a fodder and green manure for rice and other plantation crops. The flowers are small, in colour white or mauve with a brown calyx. The pods appear soon after flowering, but take as long as 10 months to mature, in the early months of the following year, to flat, elliptical pods, 8 cm long, which have no pulp but just one or two kidney-shaped kernels that still carry a tough, leathery, reddish-brown skin. The pods are beaten down with sticks and decorticated with wooden mallets to yield the kernels as two dicotyledons. Bihar and Andhra Pradesh states appear to have considerable numbers of karanja trees (Table 2).

D 3. KUSUM[84q,85q,115n,183,190,191,192]

Schleichera oleosa is one of the lesser hosts of the lac insect, palas and ziziphus species being more important. Bihar state has a particularly large number of kusum trees. Found at elevations up to about 100 m in all parts of India, the tree attains a height of 15 to 20 m, flowering between February and April and fruiting four months later. The ovoid or globose berries, about 2 cm across, have a pointed tip and are either smooth or covered with small prickles. Branches carrying the fruits are cut down by climbing the tree, since otherwise they would fall and be lost in the undergrowth. On drying the seeds, the pulp sticks to the skin and the seeds rattle inside. The thick brown coat is broken open to yield one or two irregular, egg-shaped, compressed seeds, which are the traded commodity. During the fruiting season from June to October, about 28 to 37 kg of seed can be had per tree, and an adult can collect 20 to 28 kg daily.

An Indian Standard Specification, IS: 5294-1969, has been issued for the grading of kusum seeds required for oil-milling. The kernels are U-shaped and covered with a pink skin; they are soft and oily to the touch, and susceptible to fungus attack.

D 4. NAHOR[84r,115a,183,190]

The beautiful evergreen tree, *Mesua ferrea*, some 5 to 15 m high, is commonly found in the forests of Assam, Bihar and Karnataka. In south India are found three other variant species, locally called peria nangu, siru nangu and nir nangu. The trees tend to occur in rather difficult, snake-infested terrain on the steep banks of rivulets in thick jungle. The large flowers are up to 10 cm across, white and sweet-scented, and are used for hair decoration and to scent other medications. The flowering season occurs right round the year in various parts of the country, being from June to August in Assam, even earlier in Bihar, and from August to January in Kerala. Fruiting follows two months later. The oval fruits weigh 50 to 60 g each and are reddish, hard and some 8 cm across. Each fruit carries one round seed, or two to three conical seeds, shining brown in appearance, and with a fibrous outer cover that makes up a quarter the weight. The kernels take the shape of the fruit, but are smaller, yellow

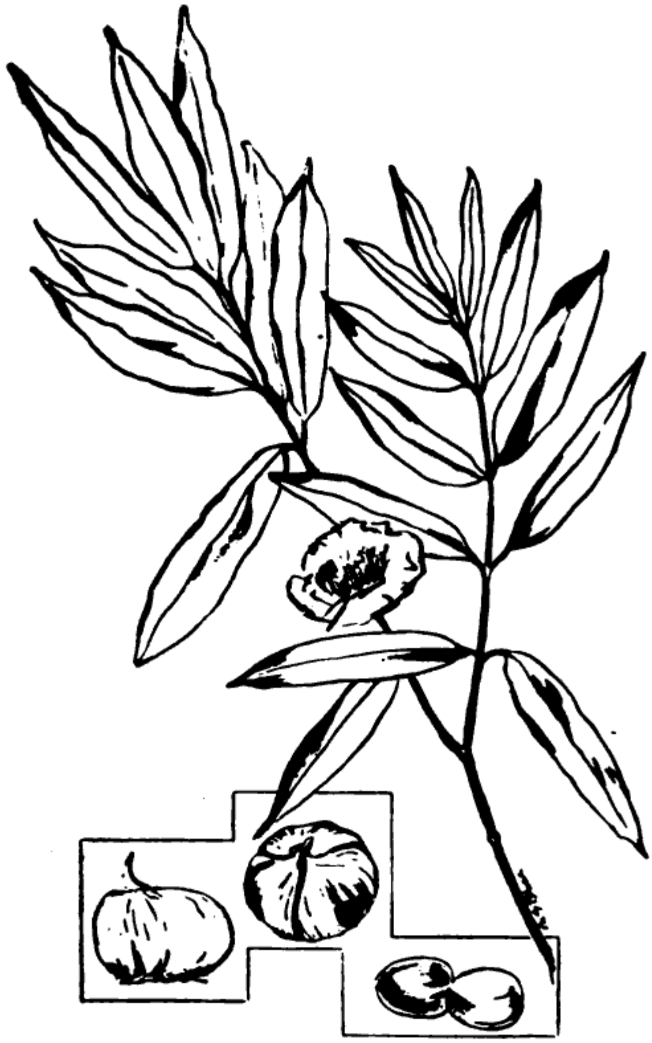

Fig. 8. Nahor: leaves, flower, fruit and seed (Courtesy: Khadi and Village Industries Commission, Bombay)

and round. The fruits are collected from the ground or using long-handled sickles, and the outer cover is removed by hand before marketing.

The nahor with its striking flowers is frequently represented in sculptures that adorn the great Buddhist stupa of the second century BC at Bharhut.

D 5. UNDI[84s,85r,115p,183,190]

Kerala state is the chief area of growth of *Calophyllum inophyllum*, with lesser amounts in several other states. Undi or pinnai generally grows by the seashore, near water courses or in sandy places. Being an evergreen with thick foliage that rises 15 m tall, it is also grown as an avenue and garden tree. The scented white flowers appear in bunches, and give rise to round or ovoid green fruits, which yellow on ripening, and are about 2 cm across, with the pulp in four compartments. Fruiting occurs twice a year, in May and November. Either these are felled, or fallen fruit is collected and dried. The single round kernel within each seed is about 1.5 cm

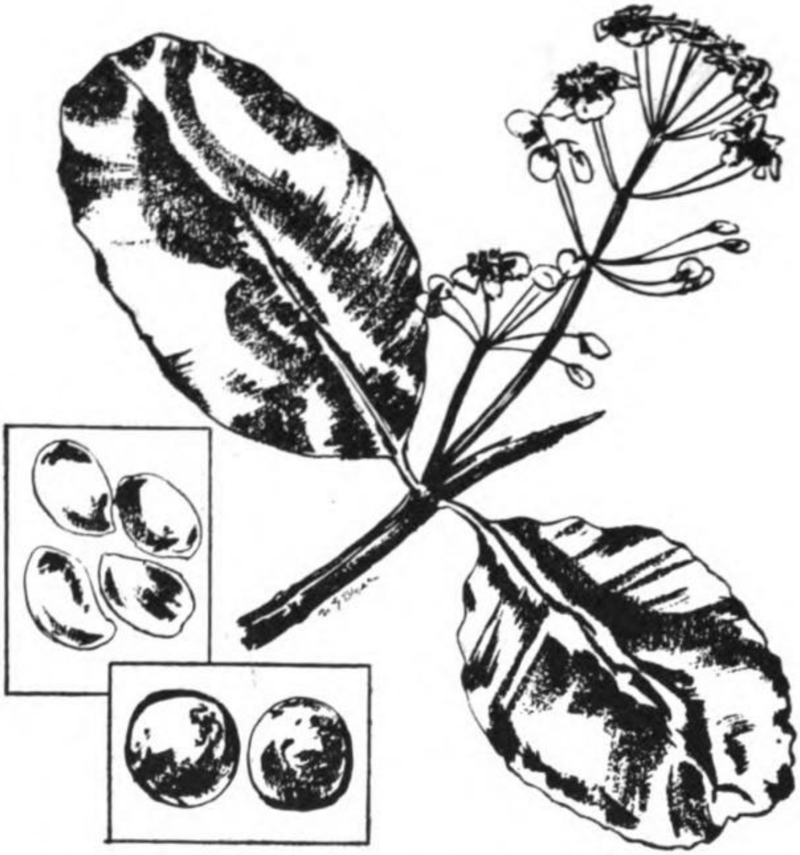

Fig. 9. Undi: leaves, flowers, fruit and seed (Courtesy: Khadi and Village Industries Commission, Bombay)

in diameter, and is enclosed in both a hard outer seed coat and a soft inner one. The articles of sale are the dried fruits, which are collected by village farmers who own the trees, or by children, and sold to the village vendor.[193] Small and large fruits fetch different prices, and are sold by number. In Orissa, undi seeds are sold by public auction.

D 6. RAYANA[84t,115g,183]

Amoora rohituka occurs both in the sub-Himalayan tracts of eastern India, in Assam, West Bengal and the North-eastern states, and also in the Western Ghats of South India. The rayana is an evergreen tree with a high crown of branches, and the cascade of white flowers mature into a three-celled berry with two superposed ovules in each cell. The kernel comprises 78 per cent of the seed, and the oil has been traditionally expressed in Bengal by roasting the seeds and then boiling with water. The oil was employed as an illuminant, and in traditional medicine.

3.5 Oilseeds carrying Vegetable Hard Fats (Group E)

E 1. MAHUA[84u,85s,85x,115r,183,190]

The Latin name, *Madhuca indica*, for what was formerly termed *Madhuca latifolia* and even earlier *Bassia latifolia*, perpetuates the Sanskrit

name madhuka for this tree. The word actually means sweet; it was originally derived from madhu, meaning honey, and refers here to the sweet taste of the flowers. A closely-related and almost indistinguishable species, *Madhuca longifolia*, was originally termed *Bassia longifolia*. The *Atharvaveda* (c. 800 BC) has references to a love spell recited under this tree, to the liquor brewed from the sugary flowers, and to the oil crushed from the seed.[118] The tree grows all over India, and seems to prefer dry, sandy and even rocky soil to rich watered land. It is particularly associated with tribal populations in Madhya Pradesh and Uttar Pradesh, since they have a liking for the flowers as food and as an alcohol source, and for the fat from the seeds for cooking. Seeds are sold by individual tribals, by Forest Tribal Federations, and through contracts or permits issued by government departments.

The *indica* (*latifolia*) variety is deciduous, while the less common *longifolia* is an evergreen or semi-evergreen. The mahua tree rises some 20m, and the pulpy, bell-shaped, cream-coloured flowers cluster at the ends of each branch. When the petals from these fall to the ground they are collected (stamens if present are carefully discarded) for use either fresh or sun-dried, when they turn reddish. They have a peculiar luscious taste with a faint mousy taint, somewhat resembling figs. Flowers are also eaten along with acidic leaves, or after frying in ghee or mahua seed fat. To make alcohol, mahua flowers are steeped in water for four days, when the sugar inverts, followed by fermentation and one or two distillations. The distilled liquor was called varuni in ancient Sanskrit literature. The spent flowers after distillation are used as an animal feed.

The Moroccan traveller, Ibn Battuta, who travelled in India in the first half of the fourteenth century AD, writes that the "fruit resembles a small pear and is very sweet . . . . . . The mahua bears fruit twice a year and from its kernels they make oil, which they use in lamps."[176] The fruits appear in May and June, or somewhat later in the south. They consist of three separate compartments, and carry from one to four shining brown seeds. The outer rind is also rich in sugars and capable of fermentation, but is usually cooked and eaten. The inner material is dried in the sun, roasted and then boiled to gruel, to which rice may also be added. The flowers and fruit are an important source of food for tribals and forest dwellers.

Fruits that have fallen or been felled by shaking the branches are collected, the rind removed by hand, and the seed decorticated by pounding with a stone. The kernels are the articles of trade, and some 20 kg can be collected by an adult in a day.

E 2, SAL[84v,85c,115s,183,190]

Though the shālā is mentioned is Sanskrit only from the fifth century AD, the tree is certainly far older than that, and probably indigenous. There are two distinct belts of *Shorea robusta* in the country. The northern belt lies on the Himalayan lower slopes to a height of about 1000 m, and

the other central belt straddles the country midway, and then turns up along the eastern coast. Thus Bihar, Madhya Pradesh and Orissa states have huge forest stands of sal. These were till recently contracted to timber merchants on a five-year basis, but have been nationalised by government since the end of 1982.

Sal wood is the most extensively used of all the timbers of north India, very largely for railway sleepers but also for all forms of domestic and public utility construction. The tree grows straight up even 30 m tall and canoes were once fashioned from it. The extruded resin is an incense, fumigant and disinfectant, besides finding limited use for caulking boats and in paints. The leaves are employed as a green manure and are fashioned into bidis for smoking, eating platters and drinking bowls.

The small yellow flowers appear in the axils or terminal panicles as clusters. Flowering is somewhat random in each tree, with some evidence of a two- or three-year cycle. The flowers cover the trees and are a favourite of honeybees. The fruits appear just prior to the monsoon, and consist of a single pea-sized seed enclosed by three 'flying' sepals and two smaller ones, which enable the fruit to be spun gracefully in the air (Plate 9). The whole may vary from 10 to 17 cm in total length. The fruits spiral down forming a carpet, and are swept together and collected by hand. The onset of June rains makes this a difficult task, and moreover wetting ruins the quality of the seed fat. A massive effort for two or three weeks is necessary to finish seed collection before the monsoon breaks, and thereafter to protect the seeds from insect attack in storage by fumigation with aluminium phosphide tablets.

The seeds have been eaten for centuries after mixing with wood ash, boiling for two or three hours, washing well, mixing with mahua flowers, re-boiling and re-roasting. These steps probably remove the tannins present, besides the undesirable components in mahua flowers. It was the practice to make large quantities of this food mix to last several days. Boiling roasted and ground sal seeds with water to release fat for cooking use has also been a tribal practice.

E 3. DHUPA [84w,85u,115t,183,189b,190,194]

This handsome tree, *Vateria indica*, is almost totally found in the lower reaches of the Western Ghats of Karnataka and Kerala states, though planted elsewhere as a roadside tree. The so-called piney resin or white dammar that it exudes is a varnish base that dries pure and white, and also a traditional incense. The trees yield as much as 400 to 500 kg each of fruit, but a good season comes only about once in five years, with two lean and two average seasons in between. The oblong fruit resembles a small potato, being 6 cm long and about 18 g in weight, and appears during the rainy season from June to August. Within to three days of falling to the ground, the seed germinates and is also attacked by worms. Collection must be quickly done, followed by decortication to remove the tough, thick shell of the fruit. Traditionally this is effected one by one

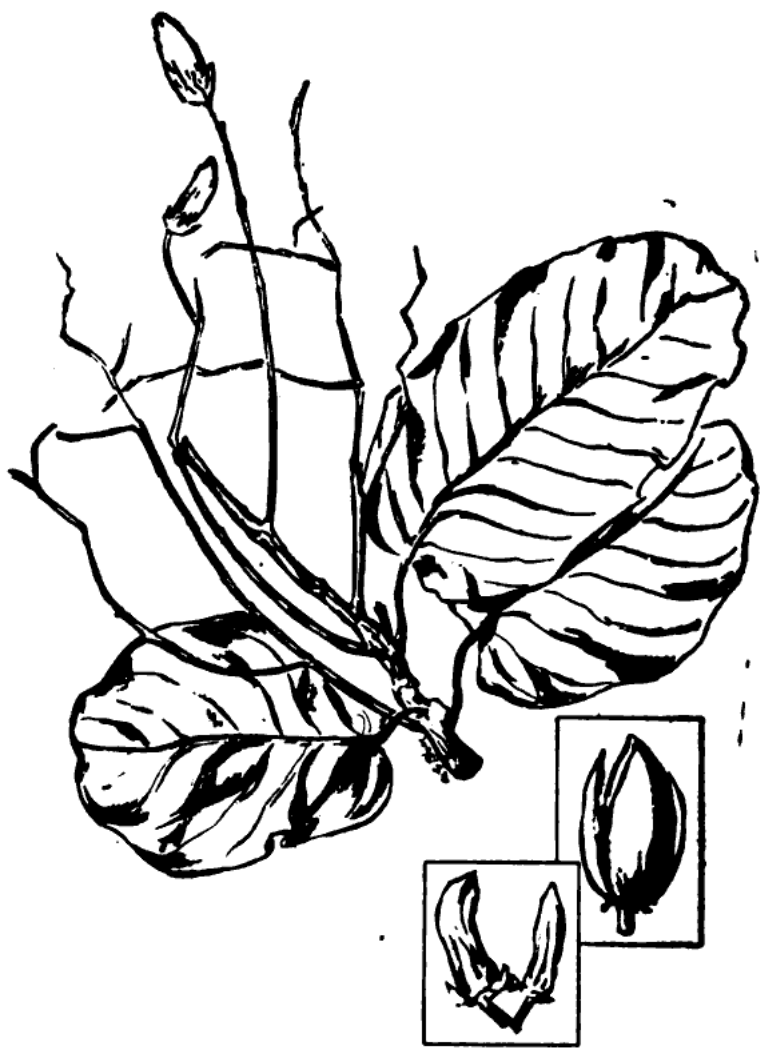

Fig. 10. Dhupa: leaves, flowers, fruit and seed (Courtesy: Khadi and Village Industries Commission, Bombay)

using stones, and is often a family occupation. Broken pieces of the large kernels are the articles offered for sale.

E 4. KOKUM[84x,85v,115u,183,140,195a]

Though *Garcinia indica* grows in most hilly regions of India, it is particularly plentiful on the Western Ghats in Karnataka and Maharashtra. It is frequently even planted, since the acidic kokum fruit constitutes a souring agent in the regional cuisine. The smooth berry is a conspicuous purple colour when ripe and about 3 cm in diameter. Linschoten's remark (1596) that "the dyers do use this fruit" as a mordant with iron is of interest. Branches of the 15 m tree are shaken with a stick to fell the fruit which is then split using sticks or stones and separated by hand. Each tree yields 60 to 80 kg of fruit which can be collected in a day by a single diligent person. Some 20 to 23 per cent of the fruit is made up of the seeds, of which five to eight occur embedded in the acidic pulp. The seeds are mixed with ashes, then rubbed dry, and sold.

E 5. TAMAL[84y,85w,115v,195b,196]

Garcinia morella is tamala in Sanskrit. Its resin exudate is the gamboge pigment so familiar in the paint boxes of children. Tamal occurs in the same areas as does kokum, though less abundantly. The fruit pulp is also acidic, and the seeds are isolated and used as a source of oil.

E 6. PHULWARA[85x,196]

Earlier termed *Madhuca butyracea* and *Bassia butyracea*, the phulwara or chiura is now classed as *Diploknema butyracea* or *Aisandra butyracea*. The tree is believed to be indigenous to Nepal, but also grows in the neighbouring Kumaon hills at 600 to 1000 m, and in the Pithorgarh district of Uttar Pradesh, where some 750 tonnes of seeds are stated to be available.[197a] In Nepal, Bhutan, Sikkim and Uttar Pradesh, a total of some one million trees are estimated to be growing, the percentage proportions in these four regions being 62, 22, 8 and 8.[197b] As with many tree crops, maximum flowering and fruiting alternates with a poor out-turn once in two years, or twice in three. The yield of oil per tree is stated to be 75 kg,[78l] implying some three times this quantity of fruit. Bees feed on the flowers, and the honey is highly esteemed locally.[84z] A fine-grained jaggery, resembling that from the date palm, is made from the flowers,[84z] and also an alcoholic liquor.[115a]

The fruits are ellipsoidal, 2 to 3.5 cm long and slightly less thick, green when unripe and turning cream-coloured. The fruits are sweet and edible, with a characteristic sweet odour, and are sold in the weekly shandies in Kalimpong during May. Fruit is collected by shaking the branches, and yields can vary very widely from 50 to 800 kg per tree, with an average of perhaps 200 kg.[195c] This would mean 40,000 tonnes of seeds or 32,000 tonnes of kernels. Extensive defoliation through use of leaves as an animal feed reduces many phulwara trees to poor condition.

3.6 Oilseeds bearing Soap-making Oils (Group F)

F 1. KHAKAN-PILU[78m,115x,190,198A]

Both the names khakan and pilu are so widely used for this species that a joint name seems appropriate. Actually two species of trees, which resemble each other closely, are included in the common Indian designation. *Salvadora oleoides* is a shrub or small tree up to 5 m tall which yields sweet, red, berry-like fruit (mitha pilu).[84a'] The fruit of *S. persica*, a slightly larger, much-branched shrub or small tree, is bitter (khara pilu), and though edible, is less favoured by children because of its strong aromatic small and pungent mustard-like taste.[198] Both grow in poor sandy soils in Gujarat and western Punjab, and the profuse white to greenish-yellow flowers yield ruby-red, transparent fruits which are collected about May by plucking the twigs. At one time crowds used to go out to collect the fruit, and either eat them fresh or dry them like currants for future use.[84a'] Special groups such as the Kharva community in the Saurashtra

region of Gujarat state specialised in such collection. When the sweet fruits are eaten, the seeds tend to be lost, and it is the larger salty fruit that is available for crushing.[199] The fruits are removed from the branches using a cotton-carding device called a lothani, which is also employed to depulp the seed.[198] The tiny round seeds, about 3 mm, are sun-dried, and in the Gujarat town of Bhavnagar for example, are brought to the merchants for sale. The yield of fruit per tree is about 10 to 15 kg, just a fifth of this being seed.[183] Kernels constitute some 60 per cent, and carry 40 to 43 per cent of an oil with 45 to 50 per cent of lauric and 26 to 32 per cent of myristic acid, though on occasion the percentage of the latter can exceed that of the former.[195d] The oil is sold in bazaars under the name kharkanela, and its potential as a lathering component in soap-making is obvious.

It has been estimated that the Kutch and Saurashtra areas of Gujarat have some 30 million trees, while half that number are also estimated to grow all along 80 km of the eastern bank of the river Sabarmati in the same state.[200] Rajasthan and Gujarat are believed to have yet another 1.5 million pilu trees. Thick groves of the tree often form a greater part of desert vegetation, and have been used in the past by cattle thieves for hiding stolen animals.[84a'] Camels relish the leaves but other animals will not touch them; in horses they act as a purgative.[84a'] The trees if fully exploited could yield some 80,000 tonnes of seed and a sixth that quantity of an exceptional fat.[200]

F 2. PISA[78m,84b',115y]

Actinodaphne hookeri, the pisa, is called thalli in Tamil, and is a small tree some 5 m high that grows in the forests of Sikkim, Orissa and Assam, and in those of the Western Ghats of Kerala, Tamil Nadu and Maharashtra. Total seed availability appears to be of the order of 1000 tonnes.[196e] The flowers are valued for their honey in Mahabaleswar, a hill resort 100 km from Pune.[201] The fruits are green when raw, ripening to red berries some 1 cm across, held in a cup or disc. With the onset of the rains these fall to the ground and being so small, collection is not possible. The berries taste like fresh coconut gratings.[202] It was common in the past to cut down fruiting branches and carry them home to strip them of fruit, but this reduces fruit yields in the following year, and can further aggravate an apparent three-year flowering cycle.[203] If not depulped at once, the fruits attract fungus on storage.[183] A driage of some 35 per cent is reported,[190] and drying is not difficult.[202] The problem is that pisa trees occur deep in the forests, and fruits have often to be carried 15 km.[203] The seeds are tiny, just 8 to 13 mm long, and weigh only 0.25 g each.[195e]

Both the hulls and the kernels carry oils of very different character. The kernel oil has 90 per cent lauric acid, while the shell oil has oleic 50, palmitic 25 and lauric 15 per cent.

F 3. CHIRANDI

Litsea glutinosa, earlier termed *L. umbrosa*, *L. sebifera* and *L. chinensis*,

and medāsaka in Sanskrit is a small evergreen tree that favours the Himalayan, Assamese and Manipur ranges up to about 2500 m, where it grows 9 m tall with a straight bole.[115z] The leaves are mucilaginous, with a pleasant odour of cinnamon, and the red roots are used to make both paper and a strong string.[84c'] The fruits, 3 mm across, appear in October and November, and turn pink and then black or purple when fully ripe. The pulp together with inner shell constitutes some 40 per cent, and the kernel the rest. About 15 to 20 kg of edible fruit are borne by each tree, and in the past it was found expedient to lop the branches and remove the fruit later.[190] Both pulp and kernel carry oil, 41 per cent and 54 per cent respectively, which means that depulping will influence the nature and type of fat obtained.[190] Both appear to carry lauric acid in large amount, thus indicating potential in soap manufacture.[183] In fact chirandi fat has long been employed in Java and China for making white soap and candles.[115z]

3.7 Oilseeds with Oils of an Unusual Nature (Group G)

G 1. MAROTI[85y,196]

Two trees of the *Hydnocarpus* genus that yield medicinal oils are found in India. The tree chaulmoogra (a corruption of chaval-mugri)[84d'] is *H. kurzii*, which a century ago was classed as *Gynocardia odorata*. It flourishes in Assam and Tripura as a huge tree 16 m high, with a tall trunk and a small crown, yielding round, chocolate-brown edible fruits about 8 cm across. Each fruit carries numerous seeds that look like brown pebbles, varying in size and shape.[115a'] Chaulmoogra oil was replaced in the British Pharmacopoeia as a specific for leprosy by hydnocarpus oil which is more effective and keeps much better.[150a'] A century ago Watt mentions that two kinds of seed reached Calcutta from Chittagong in the hills, mature seeds with brown kernels that were rich in oil, and immature seeds with black seeds carrying less oil.[85y]

Hydnocarpus laurifolia, till recently termed *H. wightiana*, from the seeds of which hydnocarpus oil is derived, is a tall, much-branched evergreen tree found near water in warm moist forest areas of the Western Ghats.[204] The entire Annamalai forest range of Kerala is covered with these trees.[205] The local name in Malayalam is maravetti, shortened to maroti, and the Sanskrit name is garudaphal. The flowers are small and greenish-white, growing singly or in fascicles, and the round fruits are 10 cm across.[115a'] The fruits are plucked by climbing trees, generally about September and October, and cutting them down with long sticks that have knives at the end.[190] Straightway the thick woody rind is cut open, and the pulp picked apart to yield 10 to 15 black, conical seeds that make up about a fifth of the fruit weight.[190] Each tree yields about 100 kg of fruit or some 20 kg of seed, which is washed and sun-dried before appearing for sale at long-established markets like Alleppey.

Fig. 11. Maroti: leaves, flowers, fruit and seed (Courtesy: Khadi and Village Industries Commission, Bombay)

G 2. KAMALA[195f]

Mallotus philippinensis was known is Sanskrit as kinbil. Many Indian languages show a strong tendency to name the yellow dye obtained from the plant after the word for jaundice, for example kamila, kamela and kapila.[84e'] The shrub or small evergreen tree, with a buttressed trunk, grows throughout India up to 500 m, being particularly plentiful in Madhya Pradesh and Uttar Pradesh, and in the upper stretches of the Western Ghats.[196] The plant precedes the sal tree, killing grasses and acting as a nursemaid for it, and is also self-propagating.[115b'] The dry woody fruits are three-lobed, and are richly coated with a powdery bright orange dye. Till about a century ago, this was carefully collected in the early months of the year for two uses.[85z] One was for dyeing silk in the presence of sodium carbonate and sesame oil, and the other for expulsion of tape-worms. According to Watt, neither use is really ancient in India, and may only have been practised after about 1700 A.D.[85z] Today these uses have

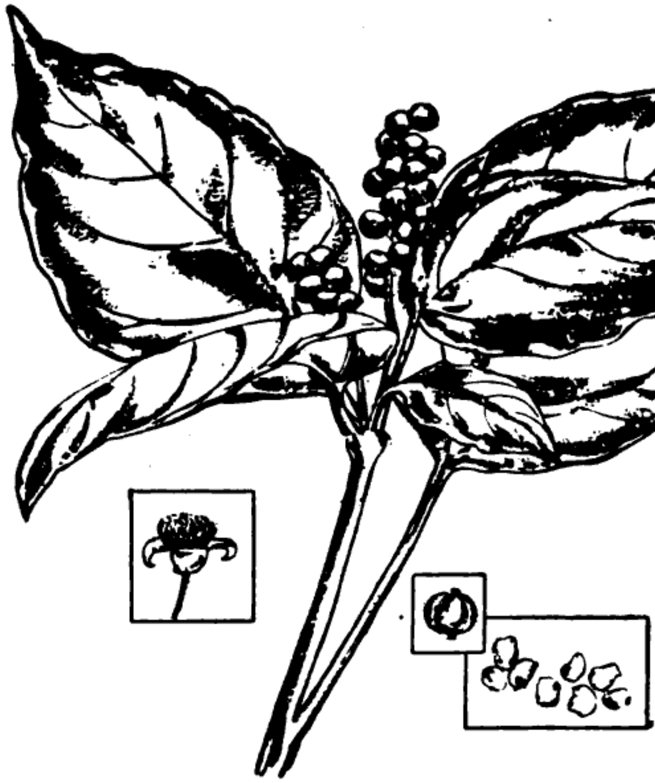

Fig. 12. Kamala: leaves, flowers, fruit and seed (Courtesy: Khadi and Village Industries Commission, Bombay)

all but vanished, kamala powder having been dropped as an anthelmintic from the British Pharmacopoeia even in 1898.[85z]

G 3. PINARI

Sterculia foetida is a straight, very tall hansome tree, 30 m high, of the Western Ghats from Konkan southwards. It is frequently also grown as an ornamental avenue tree for its stately appearance and large orange flowers, about 6 to 10 cm across, borne in panicles. The flowers have a foetid smell, even the leaves are repellent,[84f'] and the seeds are known as stinking beans.[115c',196] These are borne in woody boat-shaped follicles of a bright red colour, which split open when ripe to reveal 10 to 15 adherent globular seeds, each 1 to 2 cm across. The seeds have been roasted and eaten in times of distress, despite the nausea and purgation known to result.[115c'] The gummy exudate resembles gum tragacanth.[85a']

G 4. MALKANGUNI[196]

The Sanskrit jyotishmati or malkanguni is *Celastrus paniculatus*, a climbing shrub found all along the long Himalayan range from Kashmir to Assam up to about 1300 m, and also scattered over the rest of India.[85b'] The yellow fruits each carry one brown seed enveloped in a scarlet aril, and both aril and kernels carry oil.[115d'] Apart from the uses of the oils themselves in medicine, a remarkable product was made traditionally by destru-

ctive distillation of the seeds, sometimes in the presence of aromatic species, when a black, oily aromatic liquid called oleum nigrum distilled over.[84g'] This was sold in black or blue bottles with a high reputation as a specific for beriberi, a claim justified by modern work (Section 6.3, Item G 4).

3.8 Oilseeds from Shrubs (Group H)

H 1. RATANJYOTI

Though native to the New World, *Jatropa curcas* is now found all over India near towns and villages and as a hedge plant that is not browsed by cattle. The beautiful coppery-green leaves are a familiar sight, and though usually a low shrub, it can grow up to 4 m tall.[190,190A] The young leaves and branches are used as a green manure for coconut seedlings, and the tender leaves to feed eri silkworms in Assam if castor leaves are not available.[84h'] The milky juice dries to a bright, brittle, reddish-brown solid which oxidises silver and dyes linen black, besides being a useful traditional detergent and handwash.[85e'] The hollow twigs have been employed as pipe-stems, with a better known use as a tooth-brush which strengthens the gums. The fruit, some 2 to 3 cm in size, is green at first but turns yellow and brown on ripening, drying to three-seeded capsules, rather like castor. The seed itself closely resembles that of the castor in size and surface markings, and is in fact referred to in common parlance as wild castor (*jangli erand*). Curiously enough the oil is likewise purgative, but much more drastic than is castor oil, though from a different cause. While it is hydroxy fatty acid glycerides that cause castor oil purgation, ratanjyothi seed carries a toxalbumin called curcin, and a resinous lipid associate called curcasin (Section 6.3, Item H 1). The seeds are tasty, but numerous causes of death by poisoning after eating them have been recorded.[85c'] An old observation has it that removal of the seed embryo reduces the purgative effect and renders it safe and gentle.[84h'] Sterilising the kernels at 100°C in water for 15 minutes is reported to render the oil innocuous.[195g]

Plantations in Brazil, where the plant is called *pinhao*, have yielded four to six tonnes of seed, equivalent to nearly two tonnes of oil per ha.[78m] Cultivation in India is being urged based on very quick growth, two crops a year, and a 50-year longevity of the plant.[190A] Both oil and cake are inedible.

H 2. GOKHRU

Xanthium strumarium, the cockleburr, called arishta in Sanskrit and gokhru or adhasisi in Hindi, is a coarse, broad-leaved annual herb found growing near habitations all over India.[115f'] Eating the plant is reported in America and Australia to cause coma and death without pain or struggle in cattle and pigs; so it is surprising to note that the tender flowering top and two leaves are eaten in Assam after boiling them in alkaline

water, which is then discarded.[84l,115f'] The leaves also yield a yellow dye.[84l'] Interest in this plant stems from the fact that the oil yield per ha is about 600 kg, about twice that from common oilseed crops.[196] The numerous white or green flower-heads give rise to ovoid achenes enclosed in a hard shell with long spines, These are toxic to animals even in small amounts because of glycosides and other unknown constituents, but being prickly, are avoided when browsing.[115f'] The plant is rich in nitrogen, and mineralises easily if trampled into the soil.[115f']

H 3. HURHUR

Cleome icosandra (once *C. viscosa*) is a sticky herb with yellowish flowers nd long slender pods carrying the seeds. It has a distinct foeti smell, and is sometimes called the wild or dog mustard, and in Indian languages hurhur, hulhul or hurhuria.[115g'] The Bombay name kanphuti stems from use of the leaf-juice for ear aches.[84j'] It is a common rainy season weed of Bengal and south India, and is eaten cooked. The seeds are small, rough and pungent, and are comercial commmodities sold for use as condiments.[84j]

H 4. SOMRAJI

Vernonia anthelmintica (earlier classed as *Centratherum anthelmintica*) is a tall robust leafy annual that grows throughout India up to 2000 m. The fruits are pubescent achenes about 5 mm long, with 10 ribs.[115h'] The Sanskrit name is somaraji, and the plant is mentioned in the *Amarakōsa*[118] of about 400 AD as a highly-reputed internal remedy for various skin diseases like leucoderma, psoriasis and leprosy, and even according to Baden Powell as "a valuable remedy for prolonging life, restoring youth, and preventing the hair turning grey."[84k']

H 5. ARGEMONE

An American import that has run wild in India, *Argemone mexicana* betrays its foreign origin in one of its names, farangi-dhatura, other names being datturi or datheri.[84l'] It is a spiny-leaved annual, self-sown, with bright yellow flowers. The prickly pods resemble goblets, and carry 50 dry black seeds that resemble the mustard, and can be had simply by tipping over the capsule.[115l] A century ago Watt wrote: "In Bengal, and more or less throughout India, the seed is collected and pressed for the oil, which is yielded as copiously as that from the mustard seed."[84l'] Once used in lamps, and for ulcers and skin conditions, the oil is now frequently a source of contamination of edible oils like mustard. Even in very small quantities, it causes dropsy and glaucoma and is now a menace (Section 6.3, Item H 5). Baden Powell states that this plant is the *fico del inferno* of the Spaniards, who consider the seeds more narcotic than opium,[84l'] though this is doubtful. The plant carries the alkaloids berberine and protopine,[115l] and the seed sanguinarine (Section 6.3).

3.9 Oilseeds Derived from Trees that Yield Other Commercial Products (Group I)

There are several trees that are not specially cultivated, but which nevertheless yield products of commercial value. Good examples are the three species of trees that each bear pods containing a silky floss. The latter is extensively collected for use in stuffing pillows, mattresses and quilted coverlets called razais. Carding of the floss yields the seeds in bulk. Likewise the acidic flesh of the pods of the tamarind is collected, deseeded, and pressed into balls that are sold for use as a common souring agent in south Indian kitchens. Most of these trees are of hoary origin.

I 1. AKRA

The great Moghul emperor Akbar is reputed by legend to have got his name from having been born under an ak bush.[85d'] Two forms, otherwise very similar, are known: the purple flowered and scented akanda (Sanskrit arka), *Calotropis gigantea*, and the white-flowered akanda (Sanskrit-alarka) or *C. procera*. The akra (a twist of the Sanskrit arka) or madar (derived from the Sanskrit mandara) is also called the sun leaf or lightning leaf, arkaparna, from which arose a tradition of its blinding properties. The spreading erect bush frequents wastelands in the warm moist tracts of Bengal, Assam and south India. The stem yields a rubbery gum on incision and the bark a fibre that is strong, but poor in yield and also too short.[85d'] The seed floss is very white and soft, with a beautiful silky gloss, and was at one time spun and woven into beautiful textiles and carpets in Bengal and Orissa. Cesar Frederick between 1563 and 1567 speaks of the 'cloth of herbes', and of "a kind of silke which groweth among the woodes without any labour of man". Around 1610, Pyrard says that the silk herb is brighter than silk itself, and some 80 years later Alexander Hamilton mentions "ginghams, pinascos, and several other goods for exportation" made of this silk cotton.[85f'] Today it is only used for stuffing and rarely for weaving,[115j'] and the carded seeds that are collected are available for extraction of oil. Some 500 tonnes were actually processed in 1984-85.

I 2. SIMUL

The true or red silk cotton tree is *Bombax ceiba*, earlier variously classified as *Salmalia malabaricum*, *Bombax malabaricum* and *Ceiba malabaricum*. It is the Sanskrit salmali (Hindi simul or semul), raktapushpa or kantakadruma,[85e'] names arising from its numerous fleshy and striking flowers, 10 to 13 cm across, bright crimson, yellow or orange in colour, clustered at the very tip of the branches with their petals folded back.[115k'] The lofty tree is buttressed at the base and grows throughout the hotter forests of India. It is very ancient, since the earliest Sanskrit work, the *Rigveda* of about 1500 BC, recommends simul wood for making the bridal car.[36b] Packed into a capsule 10 to 20 cm across is a silky floss which is water-repellent, buoyant and widely used for stuffing. It resembles Java

kapok, but is not as white in colour. In the floss are embedded numerous small ovoid seeds that carry oil.

I 3. KAPOK

Salmali with its red flowers is sometimes called Indian kapok, but the true kapok of Java is *Ceiba pentandra* (formerly termed *Eriodendron anfractuosum)*. From the colour of its flowers this is called the white silk cotton in English, *sveta salmali* in Sanskrit and *safed simul* in Hindi.[85f'] The tree goes straight up, with regular lateral branches jutting out at right angles (Plate 10). The oblong capsules are some 15 cm long and 5 cm across, with numerous seeds embedded in a shiny, white, water-repellent floss.[115l'] The tree is fairly plentiful in parts of western and southern India, being planted largely round villages and temples.[85f'] Possibly it is not truly indigenous to India, but must have come in at some early date, perhaps from Indonesia.

I 4. BAHEDA[85g,115m']

The genus *Terminalia* has some 10 species growing in India, all of ancient lineage. The baheda, also called vibhitaka, finds mention in the *Rigveda* itself. *T. belerica*, commonly baheda, baira or the beleric myrobalan, is a large deciduous tree common on the lower slopes of forests all over India. The fruit is a widely-used tanning agent, though believed to be inferior to two other members of the genus, *T. chebula*, the chebulic myrobalan, and *T. tomentosa*. The gums of all the species are used as drugs, and the wood for house building, cart-making and the like. Baheda fruit is eaten when fresh by goats, sheep, cattle and monkeys, and carries one seed 2 to 3 cm in diameter. The kernel is edible and eaten on occasion, but in quantity is said to produce intoxication.

I 5. PALAS

Three trees are important as host for the lac insect, the exudations of which yield lac and shellac. These trees are *Butea monosperma* or palas, *Ziziphus mauritiana* or ber, and *Schleichera oleosa* or kusum. From these three hosts 95 per cent of all Indian lac is produced, and 85 per cent from the first two alone.[206] Lac itself is a very old material: in the *Mahābhārata*, an inflammable house of lac and wax was built by the Kauravās to destroy their rivals, the noble Pāndavās, though in the event the plan miscarried.[207] The palas tree is well-known all over the lowlands of India, especially conspicious when its brilliant orange crown of closely-packed flowers appears at the beginning of the hot season, earning it the title "flame of the forest". The flowers of *Butea monosperma* (which earlier was termed *B. frondosa*) give a fugitive yellow dye; for this reason, the dye was traditionally employed during the Hōli festival, which is celebrated by drenching friends with coloured water.[85h'] The flowers, with their black calyx, resemble a parrot's beak and yield to dark brown buds and in turn to pale green pods.[115n'] These are borne from about the end

of April and become yellowish-brown on ripening, with a hairy coating of silver-white fibres. Though 15 to 20 cm long and 2.5 to 5 cm broad, the pods are light in weight and easily scattered by the wind. Each pod carries a single, flat, kidney-shaped, reddish-brown seed, and 1 kg of kernels can be had per tree. Seed collectors decorticate the pods using mallets, and the kernels are sold.[190] The large leaves which appear after the flowers have gone are used for wrapping and serving articles of food.[85h']

In Sanskrit, the palasa, also called parna and kimsuka, finds mention both in the ancient *Rigveda* and the later *Atharvaveda* as an auspicious wood (Section 4.2, Item I 5).

I 6. TEAK

Tectona grandis, sagwan in Hindi, is indigenous to India and has always been its most important building timber. Teak grows in plantations covering 7.3 million ha in many parts of the country.[190] The durability of the wood arises from the large quantity of fluid resinous matter that fills the pores, and confers resistance against both insects and water.[85l] A tree at least 2000 years old is still in existence in the Karli cave, midway between Bombay and Pune.[85l'] The fruits appear about November to February and fall to the ground; they can be collected in a jute bag, and the calyx portions separated by beating, followed by winnowing.[85l'] The seeds are very small and light in weight (two to three seeds weigh just a gram), constituting a drawback to their utilisation for processing.[208]

I 7. TAMARIND

The English name comes from tamar-e-hind, or date-of-India, given to it by the Arabs. The chief Sanskrit name chinchapala is believed to be an early Dravidian word, the other Sanskrit name being tintidika.[80c] The current Hindi term is imli, and the Tamil word puli for tamarind pulp is also the general word for sourness. The handsome evergreen tree grows all over India, but is particularly abundant in the southern plateau. It is believed to be originally of African origin, but long acclimatised. The pods, some 15 cm long, carry an acid pulp, which comes in three types, sour, sweet and rose-red.[85j'] In the pulp are found some six to ten shiny, dark brown, squarish but flat seeds about one cm each way, with a hard woody covering. In preparing the pulp for the market, the thin and brittle outer coating of the pods is easily peeled off, after which the sticky pulp is squeezed to remove the seeds, and then pressed together into balls of various sizes for sale. The seeds yield a valuable starch called tamarind kernel powder which is used in textile sizing to the extent of 140,000 tonnes annually.[209] This is found to discolour, perhaps by oxidation of the fat present (7 per cent); defatting should improve the quality of the sizing material, and yield a useful fat besides.

3.10 Oilseeds Derived from Fruits (Group J)

Included in Group J are fruits that are either abundantly available, or those which are already converted into processed products. In the former, organised seed collection will be called for, while in the latter, seeds will be available in quantity as waste from food processing industries.

J 1. MANGO KERNEL

The mango, *Mangifera indica*, amra in Sanskrit and mangga in Tamil, is par excellence the fruit of India. Over a thousand named varieties are raised all over the country, of distinctive size, colour, texture, aroma and flavour. Alphone de Candolle in his classic *Origin of cultivated plants* (1886) believed the mango to have originated in South-East Asia or the Malay archipelago;[210] on several grounds the latter possibility is now ruled out, and today the mango is attributed to the hilly Indo-Burman region. True wild mango trees only occur now in the hills of Assam and Chittagong.[115o'] Mangoes can be raised from seed, but the parent quality is frequently distorted, and inarching was the historic style of reproduction. The Portuguese introduced grafting in their Goa settlements, and developed some fine varieties. The adventurer Niccolao Manucci, who lived in India from 1656 for over six decades and died here, mentions the Affonso (now called the Alphonso, and considered one of the finest fruits in the country), and the Parriera, the popular Piari of today.[211] The Mughal emperors used grafting techniques to raise many fine mango gardens in north India.

The amra is first noted in writing in the *Brhadāranyaka Upanishad* of about 1000 BC,[80c] and extolled about a couple of centuries later in the *Satāpatha Brāhmana*.[212] In later Sanskrit literature it appears as chuta, satakara and rasala; the last is a name meaning juicy which survives for several southern varieties.

The *Brhadāranyaka Samhitā* also mentions the amrataka or wild mango.[115o'] This is *Spondias pinnata*, which is allied to the *Mangifera* family and has fruits that resemble the mango and are used similarly.

Processing the mango to puree or slices-in-syrup yields large stones carrying the kernels. Consumption of fruit in the home is far more widespread, and collection of discarded stones needs organisation if the fat is to be recovered. A commercial start in this direction has been made.

J 2. THUMBA (Fig. 13)

J 3. WATER MELON

J 4. MUSK MELON

a) The thumba, also commonly called by its Sanskrit names indrayan or mahendravaruni, is *Citrullus colocynthis*, a fruit 8 to 10 cm across that looks rather like a small orange (Fig. 13). It is of a marbled green appearance that turns yellow on ripening, and has an intensely bitter spongy pulp.

Fig. 13. Thumba: plant and fruit (Source: After B.G.L. Swamy)

The latter is a drastic purgative, and is sold dried for the purpose after freeing it of the numerous white to brown seeds.[85k] Thumba grows as a creeper in dry soils, especially in the state of Rajasthan. It seems to be indigenous all over tropical Asia and Africa.

b) The luscious water melon with its brilliant ruby-red succulent pulp, in which are embedded innumerable mottled brown, flat and elliptical seeds, is also a *Citrullus*, the common *C. vulgaris*. The fruit appears to be indigenous both to Africa and India, since the Sanskrit name, kalinda, is believed to be of pre-Sanskrit aboriginal origin;[80c] the current common name, tarbuza, is clearly Persian. The Russian botanist Pangalo, following protracted field studies and herbarium-growing between 1930 and 1955, was convinced that the water melon was indigenous to India.[213] The water melon is raised, as are other melons, in pits or furrows on sandy river beds during the hot weather that just precedes the monsoon. The many seeds are discarded while the fruit is being eaten in the home, or when the pulp is strained before whisking into sherbets. Organised seed collection is making headway for commercial solvent extraction.

c) The fragrant musk melon, called kharbuza, is *Cucumis melo*. A related species, the cucumber *C. sativus*, has been attributed to India. The musk melon itself is however of African origin and not indigenous, judging by its Persian name and the fact that the best varieties have always been raised from seed imported from Kabul.[85l] The Emperor Babar, newly arrived in India in 1526, praised the melons of Samarkhand and lamented

their absence in India.[214a] The cream-coloured fruit, about 25 to 30 cm across, can be smooth, or ridged externally in honeycomb fashion, and the best varieties are believed to be from Lucknow in the north and Cuddapah in the south. It has been remarked that *Cucumis melo*, "introduced into Asia at a comparatively recent date, exploded with variability in a congenial environment under the guidance of man."[213] Even in households the seeds are collected, sun-dried and cracked by light pounding, the nutty-flavoured kernels being used for munching or as a dessert garnish. They are also available commercially, and are a common ingredient in processed arecanut grits that are chewed after a meal as a digestive.

J 5. LIME

J 6. SWEET ORANGE

The citrus family is a bewildering one because of the ease with which hybridisation occurs both naturally and artifically. Thus even the grapefruit may well be just a budsport, and not a true hybrid, of the pummelo.[215] Even the long-established sweet orange, *Citrus sinensis*, and the lemon, *C. limon*, may not represent true species: they are highly nucellar and therefore suspect.[215]

The origin of various forms long considered indigenous to India is thus also tempered. The centre of origin of the citrus species is believed to lie along the Himalayan foothills,[138b] with Assam the "crater-centre of citrus flora" in India.[138b] Thus while the loose-jacketed, orange-coloured santhras of the mandarin group (*C. reticulata*) were once attributed to the port Cintre in Portugal, a more likely candidate seems to be a village in the Bhutan hills called santhra-bari, meaning the home of the orange.[138b]

Four members of the acid citrus group appear to have an Indian origin.[138c] *C. medica* is the citron (Sanskrit matulunga and bijapūraka), and *C. limon* is the lemon; *C. jambhiri* or *C. latipes* is the rough lemon, and *C. karna* the lemon with an orange skin and flesh. Of the orange group, *C. sinensis*, the sweet orange, may either have originated in Assam, or may have descended from an original Indian wild orange, *C. indica*.[85m']

The Sanskrit word nimbu is even now used for *C. aurantifolia*, called the Indian lime; however it is more likely of Malaysian origin. The word nimbu itself is of pre-Sanskrit or Munda origin and would mean a very early entry of the species into India. Varthema in 1510 visited Kerala and recorded the presence of sweet oranges which be called melangoli,[85m'] and in 1519 the Emperor Babar described in meticulous detail the 10 kinds of citrus that he had encountered in India:[214b] the orange, lime, citron, santhra, large lime (Indian galgal), jambhiri, grapefruit, bitter-orange, lemon and highly acidic amal-bid(?). The Sanskrit word nagaranga for orange, and the derived Arabic narandj, have given rise to a whole host of words like the English orange, the Hindustani narangi and even the botanical *aurantium*.[85m']

The nimbu or Indian lime *(C. aurantifolia)* is extensively used domestically, as well as to make commercial cordials and juices. The sweet orange, *C. sinensis*, called mosambi or sathgudi in India, is only used as a dessert, while loose-jacketed santhras (*C. reticulata)* are preferred for industrial juices and squashes because of their bright orange colour.

J 7. PAPAYA

Carica papaya with its crown of huge leaves is a familiar sight all over India, being grown both domestically, and to a lesser extent in plantations, for its luscious orange fruits. The bright orange pulp carries hundreds of black seeds which line a central hollow, and are easily pulled off along with the thin leathery layer to which they are attached.

The papaya is indigenous to southern Mexico and Costa Rica,[165b] and an import into India, as its name in Kannada, parangimara (foreign tree), indicates.[115p'] In 1590, the chronicle of Akbar's reign, the *Ain-i-Akbari* of Abul Fazl, does not list the papaya among a long list of fruits found in the Delhi market,[160] yet just eight years later Linschoten wrote: "There is another fruit that came from the Spanish Indies, brought thence by way of the Philippines or Luzon to Malacca and so to India; it is called a papaya and much resembles a melon."[217] The Punjabi name of the plant, kharbuza, makes this point, and other names note also the resemblance of the leaves to those of the castor plant.[85n'] Even in 1656, when the papaya could have been in India a century at most, it was described by a European visitor to China as an Indian plant.[85n']

The names papaya and pawpaw are believed to be a corruption of the Caribbean term ababai.[85n] Both male and female trees exist, and the majority of the former are removed to obtain good fruit. Dwarf varieties from which fruit can be easily plucked have been developed. The latex carrying the proteolytic enzyme papain is collected for use in meat tenderising (in the kitchen green fruit pieces or fruit pastes are employed) or for the clarification of beer. Commercial manufacture of jams and bars made from the fruit would yield the seeds. These greatly resemble peppercorns, and are indeed used as their adulterant.

J 8. SITAPHAL

The *Annona* family includes a number of fruiting types, but *A. squamosa*, called the sitaphal or fruit of Sita, is by far the most popular in India. It is a green fruit the size of an orange with knuckles all over the outer surface, each corresponding to a sweet white pulpy finger within which encloses a shiny black seed. Each fruit may thus carry 30 to 50 seeds. Improved varieties have more pulp, fewer knuckles and less seed.

The plant is generally believed to be of South American origin, and all the Indian names are either from the Sanskrit sitaphala or the Arabic-Persian sharifa.[115q'] The fruit is not mentioned in the *Ain-i-Akbari* (1590) among those to be had in Delhi,[160] but in 1632 Peter Mundy observed it being sold in Agra.[176e] Even a century ago, Watt noted that the plant

occurred almost as forests in central and western India,[85o'] perhaps owing to the ready dispersal of the numerous seeds by birds and animals.

There are however some indications of occurrence in India prior to its intercourse with the New World. Charaka, about the turn of the century, mentions the sitaphala, and other names like ravanamlike and Kashmir-amlika occur in a work dated 1100 AD, which is a commentary by Dalhana on the surgical treatise of Susrutha.[80c] The sculptures at Bharhut, of the second century BC, and the Ajanta frescoes which span the fifth to the seventh centuries AD, have representations of a fruit that looks like the *A. squamosa*.[216]

During the season between October and December, the markets selling the sitaphal are densely covered with seeds discarded by those buying and consuming the soft fruit on the spot.[218] The sweet pulp with its delicate flavour is used in ice-cream.

J 9. SAPOTA

Once termed *Achras zapota*, but today reclassified as *Manilkara achras*, the fruit is in India called sapota or cheeku. Though the latter sounds Indian, it is really a corruption of the name chicle used in Mexico, the other South American name being sapodilla.[85p'] The tree was once the source of chewing gum, the exudate being tapped from the top of the trunk by chicleros who were adept at climbing the tall trees.[114b] Today synthetic resins have totally replaced natural chicle.

This Mexican plant[176c] is reported to have been brought from Mozambique to Goa,[216] while another route could have been from the Philippines via Malaysia.[127] The fruit is immensely popular all over India, growing best on the coasts near Bombay, Calcutta and Madras.[115r'] The sapota varies in colour from earth brown to a paler brown with a greenish cast, and in size from a 4 cm globe to a 10 cm ovoid. The sweet flesh is a soft deep brown, with two to three shining black pointed seeds edged with a distinct white hilium. The fruit is mostly eaten at home, no industrial products having yet been developed.

J 10. GRAPE

The grape, *Vitis vinifera*, is a truly ancient plant and fruit. Grape seeds have been excavated from Bronze Age, miocene and even tertiary deposits (some 10 million years ago) in the Middle East,[115s'] and could thus have entered India at a very early date along with numerous early migrations through the north-west. Graphic carvings of a grapevine with bunches of fruit in the stupa at Bharhut, and of a parrot holding in its beak a bunch of grapes with some leaves in the Great Stupa at Sanchi (both in Madhya Pradesh) go back to the second century BC.[1h] Mention of grapes (Sanskrit mrdvika and also draksha, a word still in use) occurs in the famous grammar of Pānini of the sixth century BC, and the *Arthasāstra* of Kautilya written about 300 BC. The latter mentions the wine, mrdvika, made from grapes, which is frequently referred to in later literature as well.[80f] Raisins,

imported then as now from Afghanistan, are repeatedly mentioned. Wild grape vines, attributed to the related species *Vitis latifolia*, were reported by Vavilov to have been abundant a century ago in Kashmir, northern Punjab and northern Pakistan.[1h]

While ancient India was thus very familiar with the grape, its actual cultivation in the country seems to have moved in cycles. Puritanical rulers who opposed its use for wine making took measures to suppress cultivation of the vine, while at other times it received encouragement.[85q'] About 1340 AD, the Moorish traveller Ibn Battuta describes it as being rare, but grown extensively in a few places, one being Daulatabad in southern Maharashtra.[176b] Yet barely a decade later, the ruler Firuz Tughluq laid out 1200 orchards in the environs of Delhi where "7 varieties of grapes" could be cultivated: as a result of this, the produce was so abundant that the price of grapes was noted to have fallen to one jital per ser, just five times the price of wheat.[66b]

By 1590, the *Ain-i-Akbari* states (attributing it as always to the great Emperor's patronage) that grapes had become plentiful in the kingdom.[160] Francois Bernier, the French doctor who ministered both to the prince Dara Shikoh and to his younger brother, the Emperor Aurangazeb, rejoiced in the "meadows and vinyards" of Kashmir.[176a] A few years later another French visitor, Jean de Thevenot (1665 to 1667) remarked on the "passion for cultivating the grape" that he had observed.[85q'] Yet during Aurangazeb's long reign of 60 years, grape production went into a decline. A brief attempt about 1876 led to some 325,000 plants being raised in the gardens of Maharaja Ranbir Singh in Punjab.[85q'] Nashik, near Bombay, and the Bangalore plateau have always produced grapes, but the quantities have been small.

Since the mid-fifties, grape growing has been revived in all these places, with a strong impetus from Hyderabad city. Specific varieties do well in each area.[219a] Bangalore has the long-established Bangalore Blue, which is *Vitis labrusca*, Hyderabad the large and prolific Anab-e-Shahi; there is the pinkish-white kali sahibi and Muscat of western India, and the small, greenish-yellow varieties like Thompson seedless that do well in north India.

Grapes are eaten domestically and also converted into jams, juices and squashes. Seeds mixed with pomace are waste products of such processing.

J 11. KAPITTHA

Popularly called the wood apple because of the hard cover on the fruit, which is the size and shape of a cricket ball, *Limonia acidissima* is an old tree, indigenous to India.[219b] It finds mention in the *Atharvaveda* (c. 800 BC) as a prescription for virility. The tree thrives up to 500 m throughout the country, and especially in the southern Deccan Plateau.[115t'] The earlier names *Feronia limonia* and *Feronia elephantum* were based on a supposed liking of elephants for the fruits. These are of two types, one small with an acidic pulp, and the other large and with a considerably sweeter pulp. The

pulp is brown and edible, much relished either as a base for sherbets, or ground into chutneys with salt, spices and oil, or as a dessert sweetened with sugar. Carrying 3 to 5 per cent pectin, the pulp makes an excellent jelly of bright purple colour, firm, quivering and of extremely agreeable flavour.[115f'] The gum exudate is highly valued as a replacement for gum arabic by dip-dyers, painters, and manufacturers of ink and varnishes, and as an ingredient of lime-based white-washes.[84m'] The fruit is sold in bazaars, and the dry, hard shells of small fruits are used as snuff boxes.

The pulp carries embedded in it numerous small compressed seeds. Strangely, in a century-old book by Cooke called *Oils and Oil-seeds of India*, these seeds are reported as yielding oil, while a Settlement Report of the Chanda district of Bengal of that time also states that "oil extracted from the fruit is a remedy against itch."[84m'] The seeds are generally strained from the pulp employing a sieve before using the latter.

3.11 Oilseeds Derived from Vegetables (Group K)

Certain vegetables that are commercially processed, or potentially capable of such treatment, would yield seeds as a byproduct. Some of these have sufficient oil to be of potential value.

K 1. AMBADI

K 2. OKRA

Hibiscus cannabinus is known in India as ambadi or gonkuru, and elsewhere as kenaf or mesta. The green leaves are ground into a popular sour chutney in the Andhra area, and the term nalida, from the Sanskrit nalita, is one in common use for several pot herbs[85r'] (see Section 3.3, Item C 7). Ambadi is indigenous to Africa,[85r'] and the late-derived Sanskrit name suggests a comparatively recent entry into India. The plant is raised for its edible leaves, and even more so for its fibre, in Karnataka and southern Maharashtra.[115u'] The fibre is obtained by retting and threshing, and is said to be "bright and glossy, but coarse and harsh", chiefly utilised for ropes, cordage, and weaving durable fishing nets.[85r'] The fruit is a pod which on drying yields the small seeds. Seed setting is without detriment to fibre production, and seeds are commercially available for processing.[100]

In practice, the lal (red) ambadi or *Hibiscus sabdariffa*, also called Red Sorrel, is frequently intermixed with ambadi and is also a source of fibre. The fruit, or rather the fleshy calyx, is used as a souring agent in curries, a thickening agent in jellies, and the source of a pleasing beverage.[115u']

A related species, the okra, called bhendi or the lady's finger in India, was till recently classed as *Hibiscus esculentus* but is now termed *Abelmoschus esculentus*. It is believed to have originated in Ethiopia or the Sudan, or perhaps in West Africa.[25c] No early Sanskrit names are forthcoming, though Charaka mentions a bhandi, which may be the same fruit. Apart from use of the tender, non-stringy fruit as an immensely popular vege-

table, the mucilage from bhendi plants is added for clarification to sugar syrup when it is boiled down to yield coarse brown sugar or jaggery.[88s']

K 3. TOMATO

The tomato is a vegetable of the New World, and had already reached an advanced stage of domestication when first taken to Europe in 1550.[220] The most likely ancestor is believed to be *Lycopersicon lycopersicum* var. *cerasiforma*, the wild cherry tomato. Like all other related species of wild tomatoes, it is native to the Andean region, which includes parts of Chile, Colombia, Ecuador, Bolivia and Peru. But Mexico is generally believed to be the centre of domestication, even the name being derived from the tomatl of the Nahua tongue.[220] Though the genus *Lycopersicon* has nine other species, the cultivated tomatoes, classed as common, cherry, large-leaved and pear, are all variants within the *lycopersicum* species.[115v']

The first European names were golden apple and love apple (*poma amoris*), and though accepted fairly easily in Italy, the aphrodisiac connotation, and the relationship of the tomato to poisonous plants like belladonna and mandrake, hindered its early popularity elsewhere.[221]

The tomato came to India not directly, as did many other South American plants, but indirectly by way of Europe through British agency.[115v'] This was perhaps as late as the eighteenth century. The tomato is not even mentioned by Watt in 1908 in *The Commercial Products of India*, and in his *Dictionary of the Economic Products of India* (1888 to 1893) the tomato is noted as being chiefly cultivated for the European population,[84n'] which was of course a very small one.

Today the tomato is an extremely popular vegetable all over India. It is processed in food factories into ketchup, and the waste, including seeds, are an ingredient of compound livestook feeds. Some 75,000 tonnes of seeds, that could yield a quarter their weight of oil, are estimated to be available.[222]

K 4. CHILLI

It is difficult to imagine cooking in India today without chillies. Yet the fact remains that all chillies are of Mexican origin, entering India perhaps about the middle of the seventeenth century, and being adopted into wide use only a century later.[85t'] Names for the chilli in most Indian languages are simply variants of the words for black pepper, which was the long-established ingredient to impart pungency. Garcia da Orta, writing in 1563, does not mention chillies,[85t'] and of the 50-odd recipes given in the *Ain-i-Akbari* that were in use in the Emperor's court in 1590, not a single one used anything but pepper for pungency.[160] However, in 1750 Rumphius described three forms of the chilli, and stated that the Indian word achar now widely used for pickle was derived from achi, which was how the Portuguese wrote the West Indian term axi for the chilli.[85t'] The word chilli itself is from the Spanish term piper a chile used in South America.

Curiously the Mexicans reverse the compliment and call Indian pepper by the term chilli.[222A]

The chilli entered India in all its diverse forms, though these belong to just two species of *Capsicum*.[115w'] One is *C. frutescens*, the tiny and very pungent bird chilly, a perennial plant in which clusters of flowers grow in the axils. This is believed to be the ancestral form of all chillies.[92c] The second species, *C. annuum*, was also once a perennial, but is now grown as an annual in many varieties.[115w'] One is var. *acuminatum*, the common bright red, thin-walled, slender form used in Indian cooking, and dried and ground to give chilli powder. Other varieties are the green chilli, the large capsicum or bell-pepper, the red pimento and the very pungent Irish chilli which is used to make Tabasco sauce. Adaptation to Indian climatic conditions was all that was required of the Mexican chilli.

The pepper plant grows only in hot, humid climates and is practically confined to Kerala state. Chillies could be grown not just in farms but in every backyard; thus they fulfilled a much-felt need in Indian cooking practice, and were rapidly adopted by the people.

Chilli seeds are removed if less pungent chilli powder is required, and would thus be available for processing. Some 270,000 tonnes of seed that could yield 67,000 tonnes of oil are estimated to be available.[223]

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PART B

CULTURAL ASSOCIATIONS

CHAPTER 4

Cultural Aspects

4.1 Mythological and Historical Associations of Oilseed Plants

Tree Veneration

Veneration of trees is very ancient in India.[1a] Indus Valley seals of about 2000 BC show that trees were already regarded as sacred, and even today it is common to see small shrines erected below trees, and strips of cloth tied to them to register vows. Some trees are sacred for their great utility. Others are revered as the temporary home of spirits or demons which can detach themselves, enter living men and women and cause problems.[2a] In Vedic lore, seven trees were considered specially sacred,[3a] and these includes the akra (*Calotropis gigantea*), the seeds of which are a source of oil. Other sacred plants are the mango, baheda (*Terminalia belerica*), neem (*Melia indica*) and coconut, and cutting them down is considered a sin.[4] When the daily homan is performed in a Brahmin household, twigs from one of the sacred trees must be ritually thrown into the consecrated brazier,[5a] but as a general rule even withered branches of sacred trees are not allowed to be burnt.[6a] Even watering these trees is an act of merit,[7] and the same ceremonies attend their planting and consecration as for setting up a household idol.[6a] In certain parts of India, patches of forest were identified with village deities, and the produce from them could only be used for meeting temple needs; even in 1956, these devarakadus (forests of god) covered 3,600 ha in Karnataka State alone.[8] Similar forests existed in Berar, and the "sacred groves of Mathura, where Lord Krishna sported as a youth," were likewise protected for centuries.[8] All are now being encroached upon.

A story central to Hindu mythology concerns the churning of the ocean at the behest of Vishnu when the gods sought his help against encroaching demons:[6b]

"Collect all plants and herbs
Of diverse kinds from every quarter; cast them
Into the sea of milk; take Mandara,
The mountain, for a churning stick, and Vasuki,
The serpent for a rope; together churn

The ocean to produce the beverage
Source of all strength and immortality—
Then reckon on mine aid: I will take care,
Your foes shall share your toil, but not partake,
In its reward, or drink th' immortal draught.
Thus by the god of gods advised, the host
United in alliance with the demons.
Straightway they gathered various herbs, and cast them,
Into the waters; then they took the mountain,
To serve as churning-staff, and next the snake
To serve as cord, and in the ocean's midst,
Hari himself, present in tortoise form,
Became a pivot for the churning-staff
Then did they churn the sea of milk; and first
Out of the waters rose the sacred cow—
God-worshipped Surabhi—eternal fountain
Of milk and offerings of butter; next,
While holy Siddhas wondered at the sight,
With eyes all rolling, Varuni uprose—
Goddess of Wine. Then from the whirlpool sprang
Fair Parijata, tree of Paradise, delight
Of heavenly maidens, with its fragrant blossoms
Perfuming the whole world. Th' Apsarasas,
Troop of celestial nymphs, matchless in grace,
Perfect in loveliness, were next produced.
Then from the sea uprose the cool-rayed moon,
Which Mahadeva seized: terrific poison
Next issued from the waters—this the snake-gods
Claimed as their own. Then, seated on a lotus,
Beauty's bright goddess, peerless Sri, arose,
Out of the waves; and with her, robed in white,
Came forth Dhanavantari, the gods' physician
High in his hand he bore the cup of nectar—
Life-giving draught—longed for by gods and demons."

The ceaseless labour to produce anything worthwhile, in this case 14 objects of inestimable value, is the moral of the tale.[3b] The poison that came out of the churning and could otherwise have destroyed the world was drunk by Shiva and turned his neck blue. The nectar which Dhanavantari carried (Fig. 14) created the neem tree. Another tree, the parijata, that sprang from the ocean was termed kalpadruma, granting all desired.[2a]

By Vedic sanction, certain vows are always taken under trees. Few will utter an untruth under a neem tree, which is why open-air courts of justice are frequently held under them.[2b] The marriage of trees is believed to have mystic significance. A neem tree is frequently married to the peepal, or a mango to the tamarind.[3a] In one of the Jataka tales of the

Fig. 14. Dhanvantari emerges from the churning of the ocean bearing the immortal nectar

Buddha's adventures in his previous lives,[9] a neem tree married to a mango tree by a gardener renders bitter the fruit of the latter, and the moral about keeping bad company is made. In one community, where a a third marriage is not legally allowed, the difficulty is got over by a token third marriage to a tree, and followed by the real fourth one, against which there is no ban.[2b]

In the life of Lord Buddha, many key events were associated with trees. This has left a permanent mark of tree veneration on Buddhist belief. The mother of Buddha was travelling in her litter when she felt birth pains: entering a grove of sal trees, she grasped a branch for support and gave birth standing, while the sal tree shed flowers softly on the newborn child (Plate 11). After long soul-searching, Buddha receiving enlightment under a bodhi or pippali (peepal) tree (*Ficus religiosa*) which Yuan Chwang,[10] the Chinese traveller, visited 1200 years later: "In the old days, when Buddha was alive, it was several hundred feet high. Although it has often been ignored by cutting, it is still 40 to 50 feet in height . . . The leaves wither not either in winter or summer, but they remain shining and glistening all the year round without change." And again, at Kusinagara, "we come to the sal grove . . . the bark (of this tree) is greenish-blue, and its leaves are white and very shining and lustrous. There are four trees in pairs, of equal height; this is the place where the Buddha died." And of the University of Nalanda, where the Chinese scholar studied: "The deep translucent ponds bear on their surface the blue lotus, intermingled with the kanaka (*Butea frondosa*

or palas) flowers of deep red colour, and at intervals the mango groves spread their shade overall."

MYTHOLOGICAL ORIGINS AND ASSOCIATION

Source: Even the Vedic texts, ancient as they are, refer to tales that already existed as legends. These are known as Itihasa,[11] heroic tales which were drawn upon in fashioning, for example, that great epic, the *Mahabharata*. The tales of the origin of many Indian plants have their beginning in the Itihasas. The Puranas, originally 18 in number, succeeded the Itihasas though very much later; they also speak of the creation of the universe and the genealogy of gods and patriarchs, and are again a source of many mythological tales of the origin of plants and trees.

Sesame: According to a tale incorporated in the *Mahabharata*, sesame seeds sprang from the limbs of the rishi Kashyapa,[12] who is believed to have played an important part in the work of creation. He is one of the maharishis (great sages), and is believed by some to have had very diverse offspring which included demons, reptiles and birds.[11] According to the *Brahmapurana*, the sesame was created after prolonged penance by Yama, lord of death.[13]

Rape-mustard: No mythological origin is attributed to these plants. In mythological ritual also, the seeds play only a minor part. The *Yagnavalkya Smriti* (the first to the second century AD) ordains that the god Vinayaka (overcomer of difficulties, and another name for Ganesa) should be bathed in a mixture of ghee and mustard paste applied on the head of the idol, and then flowers and mustard seed offered.[14]

Coconut: The *Vishnu Purana* tells the tale of how the coconut tree came into being.[12] Practising austerities, the sage Vishwamitra, one of the seven maharishis, acquired so much power that he could exalt his friend, King Trisankhu, bodily into the heaven of Indra. This annoyed the latter so much that he caught the body of the king and hurled it down. Vishwamitra stopped the fall in mid-air and propped him there with a long pole (Plate 12). In course of time this took the form of the tall and unbranched coconut tree, carrying nuts that bear the long hair of the king, and a face with two eyes.

Bengal sports a young Krishna figure called *Narugopal*, the naru (coconut) arising from him holding in his hand a sweetmeat made of sugared coconut shreds.

Neem: The numerous virtues of the neem tree find explanation in a mythological tale.[15] After the mighty churning of the ocean at Vishnu's command (see above), Dhanavantari was carrying the precious ambrosia, amrita, in a vessel to heaven. A few drops that fell to earth alighted on the neem tree and transformed it into a medical panacea. Another legend connected with the neem tree is that of the Nimbaraks, a special sect of Vishnu-followers who worship the sun.[2c,15] The sun god Suraj Narayan invited a baragi, a wandering ascetic, to dine, prepared the food, but forgot to call his guest till after the sun had set. These ascetics will not eat

after nightfall, but Suraj Narayan descended on the neem tree under which the feast was spread, and continued to shine till it was over.

The neem tree is sacred to the gods of all diseases but particularly to the goddess of the smallpox, Sitala and her six sisters,[2b] and the tree is often worshipped against this dread affliction.

The founder of one Vaishnava cult, called Chaitanyadeva, was born in Bengal in 1485; by tradition this occurred under a neem tree, and he was given the sobriquet Nimai.[16] The opposition he underwent in trying to transform society has been set to verse:[17a]

"Discarding the name Nimai, he now calls himself Gaurhari[a],
He has undermined the Hindu religion and started a heresy.
The lower orders are now singing the name of Krishna:
The name of god is known to be the great incantation,
If everyone were to hear it, the incantation loses its potency.
You are the master of the village, everyone is your subject:
Summon Nimai and send him into exile."

[a]Gaurhari = Servant of Bengal

Some 'miracle' tales concerning the neem have been recorded.[16] At Mandya in Karnataka. the leaves of a neem tree overhanging a temple are not bitter, yet others on the same tree are. In another Karnataka village, Kokatnur near Kollegal, a huge neem tree 20 m high has grown grafted on and enveloped by the aerial branches of a banyan tree, with just its crown visible: again these neem leaves are not bitter, while those of other trees nearby are.

Mahua: Mythology offers no tale of the origin of *Madhuca indica*, but the *Atharvaveda* (c. 1200 BC) records that a love spell has to be recited under this tree.[17A] The *Usana Samhita* prohibits a student from studying under it.[18a] The *Bhavisya Purana* (dated from about 400 BC onwards) enjoins that, to get male progeny, the goddess Gauri and the mahua tree be worshipped on February 22, which was denoted *Madhuka trittiya*.[19a]

Sal: The association of the sal tree with both the birth and death of Buddha has been described. In one of the Jataka tales,[12] a king chose an enormous old sal tree with which to build a palace with just one supporting column. The tree pleaded with the king to be cut down piecemeal and not felled in one operation, not far himself, but because of the pain and death it would bring to the numerous sal offspring growing round him. The king was so touched that he gave up his plan : in the event, the large tree was the Buddha himself in a previous incarnation.

In the *Ramayana*, Rama demonstrated his powers in archery to the monkey king Sugreeva, and won him over to his cause of rescuing Sita from the clutches of the demon Ravana.[12] He shot an arrow at seven sal trees standing in a row; the arrow pierced these, and returned thereafter to its quiver.

A myth of central India records how mother earth chose a Nanga Baiga tribal as her lord. On her way home, she complained of not having circumvented a pole in the customary manner: she repaired the omission

making use of a sal tree standing by the roadside, after which the tribe has held the tree sacred.

Baheda: The beleric myrobalan, *Terminalia belerica*, figures in the famous love story of Nala and Damayanti found in the *Mahabharata.*[12] King Nala lost his all through gambling, and in shame took service incognito as a charioteer to a king. Pretending to believe that her lord was dead, Damayanti instigated a royal trial of skill called swayamvara to seek a valiant new husband. Nala's employer went as a suitor, and on the way, in exchange for skills in charioteering and archery, he imparted his knowledge of dicing to Nala. No sooner was this done than the demon that had invaded his body fled, and took up residence in a baheda tree, which thereupon fell into disrepute. Its timber will never be used for building, being considered ill-fated.[20a]

Charms and incantations to ward off one's ill-wishers are often hung on the baheda tree.[12] The faceted fruits themselves are used as dice, since on being thrown they fall at random on any face.[12]

Palas: There appear to be at least two stories of the origin of the *Butea monosperma* tree with its scarlet orange flowers. A tribal myth from Orissa has it that the tree sprang from the feather of a falcon that had been imbued with the exhilarating drink of the gods, soma; since soma is associated with the moon goddess, Chandra, the palas tree is sacred to her.[4,12] In another tale, it was the sungod Surya who aimed at the earth an arrow, which took root to become the palas tree.[15]

Another episode connected with the palas is of an intruder sent by jealous gods, who interrupted Shiva and Parvati in amorous dalliance.[12] Enraged, Parvati cursed the gods, converting Brahma into the palas tree, and for good measure, Vishnu into the asvatta (*Ficus religiosa*) and Rudra into the vata (*F. benghalensis*).

A Buddhist Jataka tale is built around the different appearance of *Butea monosperma* to four brothers at different times of the year: when the leaves are green, when buds are sprouting, during blossom and while fruiting.[12] The accounts of the four brothers naturally differed, and the Buddha drove home the point that there were various routes to attaining nirvana. In another Jataka story, the Buddha was himself born earlier as a spirit inhabiting the palas tree.[12]

The broad triple leaves of *Butea monosperma* are held to represent the trinity: Brahma the creator, Vishnu the preserver, and Shiva the destroyer.[20b]

Tamarind: This tree symbolises Saraswati, the wife of Brahma the creator. Several stories connected with Rama account for the smallness of its leaves.[12] One was that Rama, living in a hut under the broad-leaved tree and feeling that no deprivation was involved, ordered his brother Lakshmana to split the leaves with arrows. In the other, when rain came through the leaves and put out the cooking fires, arrows with messages sent to Indra, the rain god, split the leaves. A third tribal story involved jealousy between two men, one of whom planted a banana tree with large

leaves; to counteract this, the other planted a tamarind tree, and a parrot was placed in it by his rival which pecked the leaves to pieces. Another story concerns Usha, daughter of Parvati, the wife of Shiva, who was sent to live on earth because she had hidden herself in a barrel of salt when Ganesa's head was cut off by his father Shiva in anger. The concession given to Parvati was that in certain hot months salt would not be eaten on earth, but substituted with the sour, but refreshing pulp of the tamarind fruit.

Mango: The story goes that a daughter of Surya, the sun god, who was being persecuted by a sorceress, threw herself into a pond and was transformed into a beautiful lotus.[12] A certain king desired the flower, but the sorceress burnt it and threw the ashes away. On the spot arose a mango tree, which eventually became laden with fruit. These the king collected, and when they ripened, one fell to earth and from it emerged the daughter of the sun god, whom the king recognised as his wife from a previous birth. To this day, the young leaves and buds that appear in spring symbolise the darts of Kamadeva, the god of love.[15] The play *Sakuntala* by Kalidasa (the fifth century AD) uses a mango flower as one of the five love arrows.[20c]

The mango is considered by Hindus as a transformation of Prajapati, the lord of all creatures.[20c] Shiva, during a temporary separation from his consort Parvati, sat under a mango tree till he was reunited with her.[12] Buddhists consider it sacred because the Buddha was accustomed to rest in a mango grove given to him by an admirer.[12] On another occasion, the Buddha ate a mango fruit, asked that the stone be planted and washed his hands over it—and a beautiful white mango tree sprang forth bearing flowers and fruits.[12] A sculpture at Bharhut (about 250 BC) represents the story. (see back of book jacket).

A tribal myth of Orissa relates how, after a sacrifice of a goat, a worshipper left the thigh bone accidentally behind, from which was created the mango tree.[12] Another tribal myth has it that it was the mango that brought death to the world.[12]

4.2 Products from Oilseed Plants in Daily Ritual

A 1. SESAME

Sesame seeds are among the nine homadhanya, or sacrificial grains. They are also pitrtarpana, grains to be offered to one's deceased ancestors or manes. Accordingly sesame seeds figure in a very wide range of the ceremonial rites connected with everyday Indian life. Six of these are particularly important to ensure worldly happiness in this life: pregnancy, casting of horoscope, naming ceremony, first-food ceremony, head-shaving ceremony, initiation into study, marriage, and the ceremony of parting the hair during pregnancy.[5b] Death and after-death rituals are important to the survivors. The *Mahabharata* says: "The gift of sesame is a very superior one: it produces everlasting merit."[21a] A cow made of sesame seeds, with

golden hoofs, was considered an appropriate present to the Brahmins on very special occasions,[19b] but gifts of sesame at any daily rite conferred on the bestower children, animals and wealth.[18c] At the sacred thread ceremony, when a lad is being initiated as a brahmin, the priest throws sesame seed to the four corners of the room to ward off evil spirits.[22a] At a marriage, seeds of all the nine sacred grains that have earlier been sprouted are used to represent Lakshmi as a symbol of fertility; these include rice, barley, sesame and five pulses, and at the wedding ceremony itself, they have a place of honour and may even be carried round the sacred fire by young girls. A very important symbol at many ceremonies is a ring fashioned out of the sacred darbha or kusa grass (*Desmostachya bipinnata*) which is worn on the little finger of the right hand: sesame seeds are almost as effective as this ring in many rites.[5c] The Hindu calendar of the followers of Vishnu includes 24 ekadasi days on which fasting of some character is observed: at one of these, the Shatilai coming in the dark half of the Pausha month,[21b] sesame seed is to be used in six ways: for bathing in, to anoint the body, to eat (six seeds only), to throw into drinking water, as alms to beggars, and as a sacrifice to the gods. To do this even at other times brings high merit. Sesame seed was an important ingredient of the great horse sacrifice, the asvamedha, by which a king claimed sovereignty: a horse was let loose to wander at will round the kingdom accompanied by a squad of young noblemen, and all territory that it covered was considered annexed unless challenged to arms by the local ruler.[23]

It is in ceremonies connected with death and ancestor worship that the use of sesame seeds becomes all important. On his deathbed, a dying brahmin offers 10 articles, including sesame seeds, as gifts to other brahmins to procure release from the bondage of being reborn.[5d] Immediately after the death, the chief mourner is shaved and bathed, and then performs the first ceremony, in which sesame oil is included. After the cremation is over, three stones are placed on a mound and sesame oil poured over them, and on every subsequent day up to the twelfth, the ritual includes sesame seeds and oil.[5d] The last ceremony of the heir is to sow and water the nine sacred grains, including sesame, in a clay pot, after which he has his first meal.[5d] Cakes made out of sesame seeds, boiled rice and jaggery, called tillana, are given to relatives.[13] At each anniversary, called a shraddha, offerings of sesame seeds, called pindas, are made to the spirit of the ancestor, now called a pitr.[13] These consist essentially of sesame seeds and rice, and have been sanctified by customs recorded in the Sutras from about 800 BC.[23] In fact, at each monthly anniversary shraddha after the death, it is recommended by the *Apasthamba Dharma Sutra* that one drona, or nearly 12 kg of sesame seeds, be used.[24] The word tilanjali derived from tila (=sesame) carries the connotation of a final goodbye.[13]

Some shraddhas are unconnected with ancestors.[21c] On new moon days the moon (Soma) visits the earth; food must be provided for the spirits, and sesame seeds and rice play their part. If the food is mixed with ghee or oil, the satisfaction of the ancestors is greater and lasts a longer time. At

the birth festival (*ashtami*) of Bhisma, and at the defeat by Vishnu of Yama (*Naraka Chaturdasi*), again sesame seed and oil play an important role.

Among the items that can be eaten as a purificatory rite for the crime of killing a cow is sesame oilcake.[18c] In fact oilcakes were permitted as food even to Buddhist monks to whom many foods were taboo, and sesame cake was particularly relished.[25a] The use of sesame seeds even entered Buddhist funeral rights, being placed in three vessels at the ceremony. Later sesame seeds played a part in Jain rites, as described in a book on their rituals, the *Vidhiprapa*, compiled in 1307 AD.[23] Those who renounced the world, either as hermits or forest-dwellers (vanaprastha), or as wandering monks (sannyasins), also abjured all cooked and cultivated foods in favour of uncultivated grains that grew wild. In this context mention is made very early in Vedic literature, the *Satapatha Brahmana* and the *Taittriya Samhita* (about 1000 BC), of a wild sesame,[23] called jartila, which they could use: the fact is of both cultural and botanical interest.

Sesame oil has a significance of its own, apart from the seed. Covering oneself with it from head to toe, rubbing it in, allowing the oil to get absorbed, and then washing it off is considered to promote 'coolness', a healthy skin, and good muscle tone. Guests will be offered oil before important ceremonies to have an oil bath and purify themselves.[5g] At the first tonsure ceremony of a boy when about three years old, he will be rubbed down with oil and bathed in hot water, and then have his forehead daubed with sandal paste.[5h] Even corpses were at one time anointed with oil by the nearest relatives before being taken to the cremation ground.[5g] After the funeral was over, the heir had his bath and when still wet, poured a libation of oil and water on the ground while thinking of the dead.[5d] In most Hindu communities, the food cooked or eaten in the house of mourning for 11 days will contain no foods fried in oil, or even foods in which the spices have been fried in oil prior to curry making. Among the 10 forms of trial by ordeal is the *tapta masha*, in which a masha's weight of gold has to be taken out of boiling oil by the accused by plunging his arm into it up to the elbow.[5i] Use of oil on the head and body is forbidden on days of fasting,[5j] and also by those who have renounced society, like forest dwellers and hermits. Oiling of the hair by women after the seventh month of pregnancy is also prohibited in some communities.

Even the emperor's camels in the *Ain-i-Akbari* of 1590 were allowed a quantum of oil: 2.8 kg of oil for anointing (*tatliya*) and 0.7 kg for injection into the nostril (*tajri*), once to three times a year.[26a]

A 3. RAPE-MUSTARD

The ritual uses of rape-mustard seed appear to have some connotation of effecting purification through disinfection. To start with, these seeds are expressly prohibited from use during ancestor or shraddha ceremonies, on the authority of the *Vishnu Dharma Sutra*.[14] The *Apasthamba Dharma Sutra* enjoins that at the monthly shraddha ceremonies, the practitioner "shall rub on his hands, feet, ears and mouth the powder of white mustard

seeds, and shall eat."[24] An early treatise decrees that red mustard seed (baja) shall be sprinkled on a fire to subdue maleficent spirits.[27a] The *Matsya Purana* of later date requires that before undertaking a certain vow, a man is to bath with panchagavya (five products of the cow) and mustard paste.[27A]

The principle of disinfection carries into other areas. Both the *Manusmriti* and the *Vasishta* and *Baudhyayana Dharma Sutras* recommend the use of the paste from white mustard seeds for the washing of linen garments.[14] White mustard seeds were commonly scattered in a room in which an expectant mother lay (as mentioned in *Kadambari*, a play written by Bana about 630 AD), used later after the infant was born, and put into the mother's bath-water on the tenth day (*Charaka Samhita*).[14]

These practices also carry a suggestion of warding off evil spirits, and as early as the *Atharvaveda* the word abhaya (inspiring fear) is used for white mustard as part of this belief.[15] Libations called arghya, which contain mustard paste among various other ingredients, are poured on certain deities as part of worship.[4] On Deepavali day in north India, women prepare from mustard oil the coryllium or lampblack, called kajal, which is used to outline the eyes of babies during the morning toilet and so ward off the evil eye;[28a] kajal is made by keeping mustard oil burning all night in a large earthen vessel with wicks, and collecting the soot on a bell-shaped earthen vessel.

The white mustard (*gaurasarsapa*) of these rituals is not true white mustard (*Brassica alba*) which was not then known in India, but the pale yellow seed of one form of sarson, *B. napus* var. *glauca.*

A 4. COCONUT

The coconut is a fruit of the southern coastline, and must have been used there as food and in ritual since remote times. However, it entered Hindu ceremonial ritual only after the Aryanisation of south India commencing about 500 BC. So useful are the tree and the fruit that the latter is called sriphala, the blessed fruit,[12] and the cutting down of a coconut tree is a very definite sin.[4] The coconut itself, on account of the three eyes, and the hair that it carries, is regarded sometimes as the trinity,[4] the Trimurti, and sometimes as the head of Shiva who had a third divine eye.[12] The full moon at Sravana, marking the end of the monsoon when fishermen resume their sorties, is dedicated to the coconut, and large numbers are thrown for propitiation into the sea.[21a]

There is hardly a ritual or ceremony into which the coconut does not enter in south India. Its leaves and inflorescence, and even green coconuts, are used for artistic and religious decoration. Coconuts are offered to guests when they arrive or depart, and to travellers to bless their journey. A house-warming or consecration is marked by a brass pitcher filled with water, with mango leaves arranged over the mouth and topped by a husked coconut, the whole being called the pitcher of overflowing plenty or purnakumba.[5e] The pitcher also is an important part of installing the tutelary

deity, the ishtadevata, in an Indian home, as well as before the engirdling of the sacred thread on a Hindu youth.[5e] An offering called naiveddya is first offered to the gods at any domestic puja. This consists of cooked rice, sugar, bananas and the like, and in south India will always be accompanied by pieces of coconut.

Marriage ceremonies of every Hindu sect in south India feature coconuts as a crucial fertility symbol. Among the Mudaliars, a metal plate (thali) with a coconut and rice on it is held by the bride's mother at the start of the wedding, and is later passed round to be blessed by all the older people present. Later, as the bridegroom ties a silk cord on the bride's wrist, she holds a coconut cupped in her hands. In a Naidu wedding, a coconut is held in common by the bride and groom seated on opposite sides, and a priest pours milk over it into a vessel below. Rattles in the shape of brass coconuts are used in the Natangu wedding ceremony as an auspicious symbol for the future. At a Kodava wedding, the bride soon after reaching the groom's home performs a domestic ritual at the household well; she breaks a dehusked coconut, held cupped in one hand, by striking it with her husband's sword held in the other. A new bride in Gujarat going to her husband's home crushes a coconut placed under the cartwheel as the starts off.[22b] When she is pregnant, at the hair-parting ceremony (simanta), she touches two coconuts placed in brass vessels and then her eyes, conveying their holiness to her.

Coconuts play a role in manly sports in South India, of which the coconut-shy of fairs in the West is doubtless a variation. In rural Bantwal in South Kanara (Karnataka), players with a husked coconut held in the palm strike each other several times with increasing force until one nut breaks, after which the winner challenges another person.[29] In the Kodagu district of Karnataka, the village headman holds aloft a coconut, and then stretches his arm horizontally; all the youths around try to snatch the nut, and the one who gets it has to run to a stone some distance away and break the nut on it—while preventing the nut from being snatched away from him by another.[30] Most festivals in Kodagu will include shooting with a gun at a target, usually a coconut tied high up on a tall tree with spathes of bananas on either side of it; the headman has the right to the first shot, after which the others try to shatter the nut. A variation is to shoot at a target on the run.

A somewhat macabre use of coconuts occurs on the death of a holy man: the body is not burnt, as is usual in India, but buried. The life force or prana must escape through the head, and so the sannyasin is buried sitting, well packed with salt, and the head cracked open by repeated blows with coconuts, after which the top is covered with a mound of earth.[3c,5f]

A 5. LINSEED

The linseed is not of any particular value in ritual, but its flowers do find a place in the *Vinayaka Uratam* puja in August and September, actually on the fourth day of the month of Bharapad.[4]

D 1. NEEM

The bitterness of its leaves, and its very definite medicinal properties, govern use of the neem in daily ritual. On the first day of the Hindu new year, *Ugadhi* or *Chaitra Vishu*, which comes in March/April when the Sun enters the sign of Aries, people eat the bitter leaves of neem with a little jaggery to symbolise acceptance of the good with the bad. The roasted flowers of the neem are used similarly.[7] The tree is sacred to the godlings of disease, and is worshipped by women in seasons when epidemics prevail.[2b] Since neem leaves repel snakes, the tree is also connected with their worship, and upright snake stones are frequently erected round its trunk.[2b] After death ceremonies, the mourners present chew neem leaves before visiting a temple,[22c] so as to drive off evil spirits that may accompany them.[2b] An element of fear surrounds the tree: among the gypsy Banjaras, a husband may say: "Lift up that neem branch if you are a chaste woman". In the 'marriage' of trees, the neem is often a partner of choice. Neem trees have long been held to purify the air, and are planted near villages, temples, and open windows; the tree has actually been found to give off more oxygen than others during daylight hours.[15]

D 2. KARANJA

Essentially a tree of the south and east of India, *Pongamia pinnata* finds few domestic uses. The leaves are very widely employed in the wet manuring of rice (see Section 1.8). The blue pea-shaped flowers are followed by small pods, and both leaves and flowers are used domestically against termites.[4] Primarily the uses are medical and will be considered in the next Chapter.

E 1. MAHUA

The *Atharvaveda* notes that the mahua dispels the poison of insects and the venom of reptiles; being fragrant and sweet, it attracts women to men, and is used in love spells and potions.[27b] The *Matsya Purana* (of about 300 AD) mentions the use of mahua flowers made up into garlands for decorating the hair, and also its use in ritual.[27A] Mahua flowers are still widely used as food by tribals in many parts of India, and also as a source of alcoholic wine and of a distilled liquor called varuni (see Section 3.5). Mahua liquor is one of 12 enumerated by the ancient sage and law-giver, Pulastya, each of which confers a different attribute like salvation, power or learning. In the Sutra literature falling between 800 and 300 BC, while brahmins are prohibited all liquor, the warrior class of kshatriyas and the trading vaisyas are allowed liquors made from mahua flowers, honey and jaggery (brown sugar), but not any distilled liquor such as the varuni distilled from mahua wine. Mahua fruits are eaten fresh or sun-dried, and indeed the tribal population all over India obtain a great deal of daily calorific sustenance from these sources, besides mahua fat. Among the Bagdi tribals, early on the wedding morning the bridegroom first goes through a mock marriage with a mahua tree.[15] He embraces it, daubs it

with vermilion, has his hand bound to it with a thread, and on being released, uses the same thread to tie a bunch of mahua leaves to his wrist. The tree is held sacred, and its cutting down a crime, by most Indian tribes.

E 2. SAL

The utility of *Shorea robusta* as a source of timber, leaf-plates or cups, food and resin has been described elsewhere (see Section 3.5). The tree in full bloom is worshipped by those desiring offspring. There appears to be a general association of sal tree with marriage, and in Bengal certain tribes use the branches for marriage ceremonies.[12] The branches are used in certain Indian villages to detect witches: the names of all women over the age of 12 are inscribed on sal pieces which are then cast into water; after four and a half hours, if any piece has withered, the woman is declared a witch.[20d] Among forest dwellers, the day fixed for a hunt is reckoned by handing over a sal branch: one leaf is plucked every day, the last one marking the morning of the hunt.[20d]

E 5. TAMAL

The orange-yellow exudate of *Garcinia morella* under its Sanskrit name *tamela* has long been employed in Karnataka for making castemarks on the foreheads of the followers of Vishnu.[20f] This is a U-mark in white with a cusp at the base, and a central orange streak.

I 1. AKRA

Calotropis gigantea was called akra in early Vedic literature, and *C. procera* alarka.[35b] Later Susruta used the term mandara: this became corrupted to madar, while arka got vernacularised to akra.[20e]

The purple flowers of *Calotropis gigantea* are worshipped in ceremonies connected with the maruts, the gods of the winds; they were friends and allies of Indra in the Vedas,[4] and later of Rama in the person of the monkey god Hanuman.[20e] The flowers are also used in south India in the worship of Shiva and of the sun god, Surya.[4] Burnt twigs of the akra are offered to Surya as part of the offerings of such twigs to planets.[6c] An akra twig amulet is believed to confer virility.[27c]

The white-flowered *Calotropis procera* is however not considered an auspicious plant.[20e] Its leaves are stated to be one of few that the camel will not eat.[20e]

I 2. SIMUL

The red to chrome-yellow flowers of *Bombax ceiba*, long called *Salmalia malabaricum*, are used in worship.[4] The simul is another tree under which, according to the *Usana Samhita*, a young Brahmin student is prohibited from studying.[18a] Perhaps this has something to do with the poison believed to be present in the plant, as noted in this quotation from the *Rigveda*: "May Agni (the god of fire) counteract against snake poison, against

poison generated in the manifold knots of trees and the like, against poison that is with the salmali tree, or is in rivers, or generated from plants".[31a]

I 5. PALAS

From early times, *Butea monosperma* has been a venerated plant. The bridal litter was recommended in the Vedas to be fashioned of palas wood, and adorned with its blossoms. Also made of this wood was the sacrificial post, or yupa, to which the animal was tethered.[27d] The *Manu Smriti* lays down that the wooden staff carried by a kshatriya (warrior) should be made of vata or khadira (*Ficus benghalensis*), of a vaisya (trader) of pippala or udumbara (*Ficus glomerata*), and of a brahmin from bilva (*Aegla marmelos*) or palasa (*Butea monosperma*)[32]. A palas wood amulet was given to a king at his installation, to impart to him its own divine strength.[27d] The wood was also permitted for use in fashioning sacred utensils, and the twigs were those to be burnt in the worship of Chandra, the moon goddess.[6c] The broad leaves of the palas were enjoined as plates (patravalis) and cups (dadiyas) for use by sannyasins, and are indeed even in everyday use since they keep for even a couple of years.[20b] They are made by fastening together several leaves as required using short bamboo splinters. They are also used in ceremonies to bless calves to ensure their becoming good milkers.[12] When a corpse cannot be found, an effigy made from palas leaves is allowed to serve as a substitute in carrying out the last rites. The *Taittriya Brahmana* decrees that use of items of palas promotes the virtue of *brahma-varcas* (brilliance or lustre).[33]

The flaming scarlet and orange flowers of the palas are used in worship of the goddess Kali.[12] The dye from the flowers is bright but fugitive, and serves admirably during the spring festival of Holi, when people in high spirits daub each other with coloured water.[15] The wood is also used to light Holi bonfires.[15] The madhubani painters of Bihar, who still paint traditional scenes, like those from the *Ramayana*, in a charming primitive style, use palas flowers as a source of orange colour and safflower florets for red.[34]

I 7. TAMARIND

Despite the widespread use of the fruit pod, the leaves and the flowers as souring agents in south Indian cooking, these materials find no place in any auspicious ceremony—perhaps for this very reason.[12] In fact the spirits in the tree are worshipped in Jambhughoda on a day called Āmli Agiāras (amli meaning tamarind).[20g] No Indian will sleep under a tamarind tree, and modern experience bears this out: when the leaves fall on tents pitched under them in wet weather, in a day or two the cloth is riddled with holes.[35a] Leaves, flowers and fruit are all employed as dyeing ancillaries, especially for the orange dye of the safflower, doubtless through the acidic materials present. Tender leaves, flowers, unripe fruit, flowers and ripe pulp are all eaten in various ways. The seed kernel forms with water a strong

paste used as a wood cement, and for sizing country blankets. The acidic pulp is used to clean and polish brass and silver.

J.1. MANGO

In the folklore of India, the mango is the wish-fulfilling tree: shut your eyes, get someone to lead you to the tree, rub mango blossoms on your hands and make a wish which will last a year.[15] The flowers are dedicated to the moon, to which they are offered on the second day of Magh in February and March, and also to Shiva during Shivaratri. The beautiful copper-coloured young leaves, and then the small green buds, are believed to symbolise the darts of the Indian cupid, Manmatha. The twigs are one of the five panch-pallavas used in Hindu ceremonies.[20c] Any auspicious event in the home, or a public function, will witness a festoon of mango leaves across the front doorway or the altar. The wood is sacred, and used in twig-burning rites as well as on funeral pyres.[12] In certain pujas, a tiny twig of mango placed in a small jar of water symbolises the first green sprouts that emerged from the primeval waters.[36]

Many tribal people in India have a mango day, when eating the fruit is forbidden. Other tribes associate the mango with male fertility, because of the resemblance of the mango fruit to a testicle. Certain tribes of Orissa when returning from a funeral have to step over a mango bark. Mango branches are used in a prophylactic rite to avert disease.[12]

4.3 Festivals, Feasts and Fasts

Social Festivals

While almost every festival in India acquires a religious association or aura, there are some in which the social characteristics dominate, suggesting indeed an origin even more ancient than the codes of religion formalised by Vedic thinkers. In most of these oilseeds or oils have some part to play.

Ugadi or *New Year's Day*: This celebrates the new moon in March or April in which ceremonial visits to friends and relatives are paid, accounts are finalised, and leases on land renewed. A few bitter leaves of neem are eaten with brown sugar, symbolic of taking the good with the bad.

Gauri Purnima, during the new moon in the month of September, is an occasion for worshipping the tools by which one practices one's trade, men and women alike paying honour through offerings of rice, sesame seed and the like. Gauri is another name for Parvati, wife of Shiva. Incidentally, these implements are always considered to be ritually pure: the *Atri Samhita* declares this of sugarcane presses and oil mills.[18b] The foot-pounder used for grains, the dhenki (p. 80), even became the vehicle of the sage Narada.[6d]

Dasara or *Mahanavami* comes a month later with the new moon in October, and is especially devoted to the memory of ancestors. New clothes are presented and teachers are honoured. Weapons are particularly honou-

red and worshipped, giving it the special name *Ayudha Puja* (sacrifice to arms). In Bengal it is the last day of *Durga Puja*, celebrating her victory over an evil demon.

Deepavali or *Divali* has a connotation of fire worship, and this feast of lamps is celebrated in end-November in every home with rejoicing, new clothes and offerings of sweets made of coconut, sesame and sugar. Fire-crackers are set off by individuals and communities. Sesame seed is charged on this day with special properties by its patron, Saturn, and is therefore used to anoint the head.

Pongal in south India, or *Makara Sankranti* in the north, celebrates the first day of the solar month, when a dark period has been left behind, and an auspicious month lies ahead as the sun turns north once again about mid-January. It is really a celebration of agriculture. In the south a pot of rice is put to the boil and just when it begins to froth over, is offered to Ganesa with cries of pongal. Cows are specially honoured with garlands of mango leaves, and with a libation of water containing neem leaves among other things. In north India, sugared sesame balls are given out with the words: "Speak sweetly to me for the rest of the year", and coconuts also come into the picture.

Holi is the community spring festival celebrating the full moon day of the month of Phalguna (March). Colour and light are in evidence: people dance and daub each other with colour during the day, and a bonfire (often built round the branch of a castor tree) is got up at nightfall.

RELIGIOUS FESTIVALS

Makara Saptami is when the sun-god is worshipped with eight offerings, which includes the sesame, on the seventh day of the light half of Magha (February). The eleventh day is specially auspicious to Vishnu, and is a day of expiation of sins: it is called the feast of the six sesamums, since the seed plays a part in each of the six stages of this rite.[1b]

Ganesh Chaturthi pays homage to the god with the elephant head, whose protuberant belly resembling a granary, and prominent ears a *surpa* or winnowing tray, show his link with agriculture. Ganesa is the remover of obstacles, whose blessings are sought at the start of any new venture. His favourite food is the modaka, an envelope of rice filled with sugared coconut and sesame seeds and fried in oil. Sesame seeds are not only eaten, but offered during the puja.[19b] Offering rice cooked with sesame to Ganesa is mentioned in the *Yajnavalkya Smriti*.[23]

Shivaratri is the night of vigil to Shiva in mid-February, when he is worshipped in particular with neem leaves. This commemorates an incident when a hunter stayed up all night on a neem tree.[5k] As he shivered in the cold, dew and neem leaves fell like a benediction on a Shiva shrine below the tree. This earned the gratitude of the god, and a place in his heaven for the hunter, besides release from bondage in hell with Yama, the god of death.

Ramanavami in March or April, the birthday of Rama, is a day of rejoicing with bright lights and temple visits.

Kojagara Lakshmi puja, five days after Dasara, is an abbreviation of the question: "Narikel jaln, peethra kojagara bhoomithale?" or "Who, after drinking coconut juice, is awake in the lower world?"[28c] Lakshmi asks this as she makes her annual circuit round the earth on this holy night. She is believed to bestow her favour on those who are awake, and so drinking coconut juice and keeping vigil are practised. Lakshmi is again worshipped more elaborately a fortnight later on the night of Deepavali (Fig. 15).

Fig. 15. Lakshmi, the goddess who favours white

FESTIVALS CONCEIVED WITH OILSEEDS AND OILS

Nariyal Purnima or Coconut Day is celebrated by fisher communities on the full-moon day of Sravana in July or August, when the thrust of the monsoon has abated and sea-going by fishermen can be resumed. Into the sea are cast coconuts, a piece of red silk and a crown of dried banana leaves (the last two could suggest the offering of a virgin in ancient times),[22d] with prayers and chants addressed to Varuna, the god of the sea, and to the "food-giving goddess of the waters."

At the *Tailotsava* or Oil Festival, which is celebrated at the temple in Madurai dedicated to Meenakshi, the wife of Shiva, the image of the goddess is taken out in magnificent procession, after which the head is anointed with oil, followed by a bath, and re-dressing in sumptuous new clothes.[3d]

Naraka Chaturdasi celebrates the victory of Vishnu over Narakasura, another name for the lord of hell.[21e] On this day, the Naraka fourteenth, the goddess Lakshmi is believed to dwell in oil, and anointing with oil, bathing and donning new clothes are obligatory. Every home is lit with oil-lamps, as is every Vishnu temple.

Madhuka Trittiya on February 22 every year is a festival to Gauri, wife of Shiva, and is for women only, especially those wishing to have a male child. Worship of the goddess under a mahua tree is prescribed.

Flowers and Leaves in Worship

Only certain flowers and leaves are believed to be acceptable to each god and goddess. Thus the goddess Saraswathi is the lady in white, who finds pleasing all things white: sprays of mango blossom, unripe ears of barley, grains of light-coloured pulses, white sandal paste, and sweets made with white sesame grains.[28b] Among oil-bearing trees, the flowers of kamala (*Mallotus philippinensis*) are liked by Parvati (Gauri), of undi (*Calophyllum inophyllum*) by Varalakshmi, and those of hibiscus species by Kali (Durga).[4] Shiva favours, among others, the flowers of purple akra (*Calotropis gigantea*)[35b] and Vishnu certain varieties of jasmine and lotus. Ganesa is worshipped with the white akra (*Calotropis procera*) and linseed flowers among others, and Surya, the sun god, with the white akra.

Fasts

Orthodox Hindus observe innumerable fasts or vratas. The *Bhavisya Purana* (which first appeared in 500 BC, with later accretions even to recent times) prescribes no less than 139 fasts in a year.[19a] These are of various kinds: on certain days of the lunar months, on certain days of the lunar stations, on certain days of the week, in certain months, and for periods even up to a whole year.[37] The eighth and eleventh days of the light half of every lunar month are ekadasi or fast days: the eleventh days are all sacred to Indra, and others to the Sun, Vishnu, Somnath, Krishna and Gauri.[38] A particularly important one is Vaikunta Ekadasi, celebrating the redemption of mankind by Vishnu is his incarnation of Krishna.[5k] This ekadasi is prepared for by a single saltless meal unaccompanied by vegetables the previous day, and a day-long fast, with an evening meal of fruit and cakes but not including rice.[5k]

Most fast days do not imply total abstinence from food, but restrictive and specialised eating.[37] These restrictions can be of various kinds: against cereals not raised by the plough, or left-over food, or eating only at certain hours, or eating only fruits. Use of salt and of vegetable oil, presumably because both add relish to food, is frequently forbidden. This is true of the

following fast days in the *Bhavisya Purana*: Asoka Purnima, Gospada Trittiya, Sarvatha Saptami and Sri.[19a]

4.4 Caste Associations in Oilseed Crushing

FAMILIES AND COMMUNITIES

It has been pointed out (Section 2.1) how groups of oilseed crushers developed first as artisans called tailapishakas or telikas. Later guilds of these craftsmen developed, like the Teliki One-thousand. The fact that these guilds were hereditary families shows that profession had hardened into caste, with all its built-in customs, beliefs and alliances.

Some examples of this survive to this day. The Kols of Bihar normally use a chappa of two wooden planks to press out oil (Section 8.1). When these are not to be had, they use an ordinary oilpress or ghani, but for fear of losing caste, they abjure employing oxen for traction in favour of human labour.[17b] At Seraikela in Northern Orissa state, oil mills are of three patterns (Fig. 16). One is a mill made from a single block of wood, without an outlet drain and drawn by two bullocks. The second is a unit made of a single block of wood, carrying an oil outlet and run with one animal. The third is made using two blocks of wood, one placed over the other, with an oil drain and a single bullock. The groups who work these three types of oil mills have no relations with each other, and consider them 'different'. Each group comes from a distinct cultural-linguistic background, whether Orissa, Bihar or Bengal, and has differences in food and marriage habits. The first two groups make their ghanis from the sal wood which is abundant locally, but the third is made from peepal, banyan or neem, which are claimed by its users to be superior to sal, but which are obviously simply a matter of tradition.

Ghani design is in fact strongly traditional. In general ghanis in the south do not have the drain pipe as northern ghanis do, and even if one happens to be present, it will first be plugged up before use![23] Migrations on the east and west coasts have led to local differences in ghani design and usage, as the example of Seraikela shows.

Another unusual traditional custom is that of mass marriages among the oil-miller or Ganiga community who live in the Kasargod district of Kerala State.[39] Also known as Patalis, it is believed that they migrated there from elsewhere. This community has always practised such weddings *en masse*, when say 50 pairs would get married, saving much expense, at a common ceremony called *meenamasa*. Indeed marriages conducted in the home or elsewhere are looked down upon, and even those who work elsewhere in the country come back to the small town of Perne to get married in a group ceremony.

NON-HINDU OIL-MILLERS

The brahmin, even when he took to other than priestly and learned professions in post-Vedic times, was not permitted the profession of oil

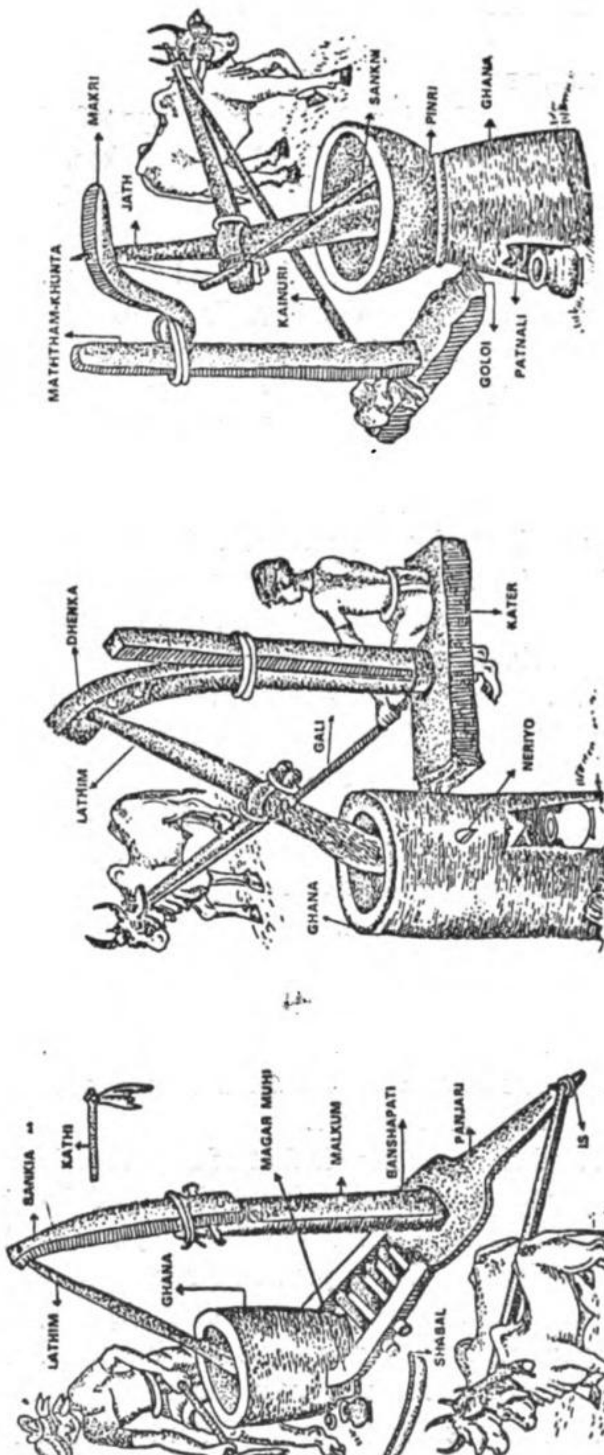


Fig. 16. Three types of ghanis used in the same area by different castes (Source: N.K. Bose[17])

crushing. It has always been a preserve of the vaisya or trading community, though in later times there was a schism between those who crushed oil, the low-caste artisans, and those who traded and made money on the commodity by acting as brokers.

About 175 BC, one of the lost tribes of Israel, fleeing Greek persecution, was shipwrecked near Navgaon in Maharashtra. The seven couples that survived took totally to an Indian language, Marathi, to Indian life-styles, and rather suprisingly, to the profession of oil pressing[39A,40] One reason suggested is that they had known the profession in Palestine and simply continued it in India. Another was that a rich oil merchant took pity on their poor plight, and taught them oil pressing, in which they persisted for generations—becoming in effect a cultural caste. Since they rested their oxen on Saturday (Shanwar), they came to be called Shanwar telis, in contrast to the Somwar (Monday) telis who rested theirs on Monday. Practically every village in Konkan had one or two Shanwar telis. The name persisted strongly, and some Jews who later became distinguished academicians have expressed their irritation at being dubbed telis by their schoolmates.[40]

Muslims have also taken to oil pressing. An epigraph dated 1264 AD from Junagadh in Saurashtra pertains to a mosque built by a sea-captain named Piroja.[41] He enjoined that the donations made and the place of worship itself should be maintained jointly by several congregations of Muslims, which include "the congregation of ghamchikas (oilmen) belonging to the town, together with their khatiba (preacher)". The photograph of traditional safflower seed processing in a ghani (Plate 22) is that of a Muslim family of Uravakunda, near Anantapur in Andhra Pradesh.

4.5 Place Names of Oleaginous Origin

Origins of Place Names

Looking for sites to excavate that might contain huge mounds of ash, derived about 2150 BC by the burning of accumulated dung from stockaded herds that numbered up to 1000, the archaeologist Allchin found to his surprise that all he had to do, 4000 years after the event, was to choose villages whose names still carried the words for cattle or for ash![42] Place names which carry the word guda (raw sugar) in inscriptions of the eleventh and the twelfth centuries AD have been identified with towns of today that have altered names, but with a similar connotation: thus Ikshugrama (ikshu=Sanskrit for sugar cane) is the modern Usgaon, and Sakaragagavam the modern Sakhargaon. Present-day Patna was once the capital of the Mauryan empire, which Kautilya, the author of the *Arthasastra*, brought into being. It was then called Pataliputra, from the trumpet-shaped towers of the patali (*Stereospermum sauveolens*); even before that it was called Kusumapura, the city of flowers.[10]

Indian towns have been named in various ways. Words for sugar, like *iksu* and *guda*, form part of many names.[43a] Nellur in Andhra Pradesh is

from nellu, paddy, and Allāmuru from allāmu, ginger.[43b] The udumbara tree, *Ficus glomerata*, gave its name to towns in Maharashtra like Umroli and Amaravati[44a] Settivāda is from setti (merchant) and Intupureva from revu, meaning port.[43b] The Karanja river in Andhra Pradesh, a tributary of the river Manjari which itself feeds the mighty Godavari, is obviously derived from the karanja tree, *Pongamia pinnata*. It was a grove of palasi trees, *Butea monosperma*, that gave its name to the battle of Plassey (1757), which turned the military tide decisively in British favour in India.

Names of Towns

Listed in Table 4 are present place names in three states in India, Andhra Pradesh,[43b] Karnataka[45] and Maharashtra,[44] that have been derived from the neem, tamarind and mango trees which perhaps at one

Table 4. Places in three Indian states named after oilseed plants[a]

	Andhra Pradesh[43a]	Karnataka[45]	Maharashtra[44]
Neem	*Vēpa, vema*	*Bevu, nimb*	*Nimb*
	Vepūraka	Bevūru	Nimgaon (Aurangabad District)
	Vembarru	Bevinahalli	Nimgaon (Baldhana District)
	Vemulūru	Nimbārgi	Nimni
	Vemūru	Nimbal	Nimbāri
	Vemula		
Tamarind	*Chinta*	*Hunise, chinch*	*Chinch*
	Chintapalli	Sora hunse	Chincholi
	Chintapura	Hunsūr	Chinchala
	Chintakunta	Hunasikatte	Chinchakheda
	Chintarela	Hunasaghatta	Chincholiphool
		Tola Hunse	Chinchavād
		Hunisehalli (now Chintapalli)	
		Chincholi	
Mango	*Māmidi*	*Māvu*	*Amba, āmra*
	Māmidi	Horamāvu	Ambar
	Māvunderu	Halasumāvu	Ambavāni
	Māvindipalli	Hulimāvu	Ambejogai
	Māvindivāda	Nelamāvu	Āmner
	Māvendi	Māvinakere	Amonle
		Māvinakatte	Ambada
		Māvalli	

[a]Italics indicate the local name of the oil-bearing material; below this are the place names occurring in the state.

time occurred there in quantity. These common trees appear to have the largest number of places named after them.

Many other oil-bearing materials described in this book have also given rise to place-names in the three states. These are shown below for Andhra Pradesh (A), Karnataka (K) and Maharashtra (M):

Sesame: *nuvvulu*, Nuvurubarasivada (A)
Mustard: *avalu*, Avakuru (A)
Castor: *haralu*, Haralukunte (K); *eranda*, Erandol (M)
Maize: *jonna*, Jonnalegedda (A)
Jute: *chunchala*, Chunchanagiri (K)
Karanja: *karanja*, Karanji, Ichalkaranji and Karanjiwadi (M)
Mahua: *mahua*, Mahudalagrama and Mohagaon (M)
Sal: *sala*, Salinde and Salve (M)
Simul: *burugu*, Burugedda, Burugapatti and Buruvudaggu (A)
-do- : *savari*, Savargaon (M)
Palas: *halas*, Halsvadi (M)
Ambadi: *gongura*. Gongura (A)
Okra: *bhendi*, Bhendigrama and Bendapundi (A)

4.6 Sayings Involving Oilseeds

Philosophical Sayings

"As oil in sesame seed, as butter in cream, as water in hidden springs, as fire in wood, so is the self seized within one's own self, when one seeks him in truth and with fervour" (*Svetasvatara Upanishad*).[46a]

"The universal being, the Brahman, is smaller than a rice grain, smaller than a mustard seed . . . . . greater than earth, greater than heaven" (*Chandyoga Upanishad*).[1c]

"From food all creatures come to be; from rain comes food, from sacrifice is rain derived, and sacrifice from works" (*Bhagavad Gita*).[46b]

"From food are all things born: by food, when born, do they grow and develop" (*Taittriya Upanishad*).[46c]

"As the worms of the bitter neem fruit seem tortured when placed in sugar solution, so also the ignorant worm, seeking the pleasures of the world of duality, fears the joy of the non-dual and the non-manifest, since he can find there no trace of the song and dance and play of the world" (*Sri Shiva-tattva*).[47]

"Shrewd people are kind only so long as they are full of affection; when this is taken away, they become like sesame oilcakes, devoid of oil" (*Vajjalagam*).[48]

Proverbs

"Til chor so bajjar chor" (Hindi): who steals a sesame seed will steal a sack.[13]

"Til til ka hisat" (Hindi): there is no oil in the sesame seeds (implying, to swear black is white).[20h]

"Dolhi et alu doodh nahi" (Hindi): all that is white is not milk.[49]

"A neem seed dropped in a beverage of sugar, honey and ghee will make it so bitter that even pouring milk on it for a thousand years will not remove the bitterness" (south India): innately wicked people are heedless of any good done to them.[5e]

CHAPTER 5

Utilisation of Oils in India

5.1 Oils for Frying

Antiquity of Frying

A copper frying pan with a handle, very like a saucepan of today, has been found at Mohenjodaro (c. 2000 BC) (Plate 13). So was a lump of charred sesame seed,[50] so it does not seem unlikely that frying in sesame oil was practised. Since numerous animals and birds were slaughtered, and fish caught, animal fats of many kinds must also have been available to the Indus Valley inhabitants for the purpose of frying. Small querns for grinding were found (Plate 14). These are very similar to those in use even today for grinding spices, which, lightly fried and blended into masalas, impart to Indian curries their distinctive flavours. Since all the elements that contribute to frying were present, the practice may well have existed even in Harappan times, given the extraordinary continuity of Indian life.

Coming to the Vedic period, the *Rigveda* of about 1500 BC mentions at least one item, a cake of cereal flour called the apupa, in conjunction with the word *ghrtavantam* meaning "cooked in ghee", which would suggest knowledge of frying.[25b] The *Dharma Sutras* (600 to 300 BC) again have apupas and also vatakas, preparations of various whole pulses and pulse flours fried in fat, which are now called vadas. Panini (c. 500 BC) mentions the fried samyava, made of barley.

Oils Used for Frying

Only *ghrta*, ghee, is ever used, in the context of a cooking fat, in the early Vedic literature. 'Shining ghee' had a purity and connotation all its own, that of having been purified by fire and itself conferring purity on cooked dishes,[51] besides being one of the five products, *panchagavya*, of the revered cow (the others were urine, dung, milk and curds). A Rigvedic hymn implores the lord of the field to "pour forth. . . copious rivers of sweetness, dripping honey like nectar and pure ghee".[46d] Sesame and mustard oils were disdained, though probably in use by non-Aryan people. But by the time of the *Sutras*, about 600 BC, frying in oils had been noted

by brahmins; and the *Arthasastra* of 300 BC has 40 references to frying, with a high place accorded moreover to sesame oil.[52] The physician Charaka recommends the use of ghee in autumn, animal body fats in spring, and oil, especially that of the sesame, in the rainy season—with a caution that it should not be used for cooking every day.[53] He muses that though non-Aryan kings used oils in their cooking, they did not feel tired, fought bravely in battle and conquered old age.[25c,53] A couple of centuries later Susruta describes a whole class of foods fried in ghee, *ghrtapakvah*, but says that fried materials are hard to digest and that oil should be used sparingly in the kitchen.[25c]

South India escaped may of these reservations in regard to the use of fat. Aryan-style veneration for ghee came in rather late, a few centuries before the start of the Christian era, and butterfat, sesame oil and coconut oil were used as appropriate to organoleptic needs.[54,55,56]

Kautilya's *Arthasastra* mentions fats extracted from the safflower, linseed, mustard and castor,[52] and the *Manu Smriti* of about the same period (the third century BC) the oils of neem, mahua, mango and ingudi (*Balanites aegyptiaca*).[25d] Clearly not all these were edible; neem oil was essentially medicinal, and ingudi oil had a special use for sprinkling on faggots in hostile rites such as the effacing of curses.[27e] Charaka adds to this list the oils of bilva (*Aegle marmelos*), priyala (*Chironji sapida*) vibhitaka (*Terminalia belerica*), karanja (*Pongamia pinnata*) and two others, vasa (perhaps *Acorus calamus*) and majja (whose identity is not clear).[52] Animal fats used were those of the pig, alligator, bear and ass; even Buddha permitted use of these to his followers if they fell sick, implying some medical connotation.[25a] About 500 AD, goat body fat is highly rated and that of the elephant considered the worst, while body fats of the cock, goose and a fish called auluki are noted.[25e] In south India, fish oil was an item traded by coastal dwellers for foods like honey and roots from hill folk.[55]

Kinds of Fried Foods

Cereal-based items: The apupa starting with the *Rigveda*, the vatakas of the *Dharmasutras* and the samyava of Panini have been noted as fried foods of the earlier period.[25f] The *Sutra* literature also mentions parpatas, the crisp papads of today, but made not from pulses but from sesame seed.[25f] The early literature of south India, of the first two centuries before and after Christ, mentions two shallow-fried dishes that are still very popular, dosai and adai.[56] These are flat circular pancakes made out of a batter of rice and pulses fermented together. The *Manasollasa*, written in 1137 AD by King Someshwara of Kalyani, a city about 160 km west of modern Hyderabad, lists rather tersely a number of shallow-fried cereal snacks.[57] Mandakas were made of wheat flour, as were variations stuffed with honey (madhumestaka), jaggery-and-mashed dhals (pahalika or polika), or savoury mixes (angara-polika). Kasara had milk, sugar and spices added, and suhali were hard wheat cakes deep fried in oils and then

coated with sugar. Wheat flour cakes with their stuffings were called patrika, samita and purana.

Pulses were frequently used in combination with cereals, but sometimes by themselves. Four pulse flours were blended in vidalapaka. Gharika was a crisp deep-fried snack made from blackgram, and katakarna one from peas and cowpeas. Pastes of cereals shaped by hand yielded vatika (the vadi or wadian of today), purika (the papadi of the present) and parika (today's bonda).

Sweetmeats have from the very start been of a fried nature, like the stuffed samyava, first made of barley flour and later of wheat. Stuffing it with sweet coconut shreds yielded ghrtapura. Stuffing with honey and ghee yielded madhusirsaka, and with jaggery pupalika. Utkarika was a rice flour preparation that used molasses and ghee, and rolling it up yielded vartika, perhaps a stuffed pancake.[57]

Fried meat dishes: The two great epics graphically describe flesh foods fried in fat. In the *Ramayana*, the father of Rama, Dasaratha, served at his sacrificial fire countless dishes of mutton, pork, chicken, and other meat, cooked either in fruit juices or fried in butter.[58] In the *Mahabharata* the food served at a picnic is described in the following terms: "Young buffalo calves roasted on spits while ghee was dropped on them; the same fried in ghee seasoned with acids, rocksalt and fragrant leaves ...... shoulders and rounds of animals dressed in ghee, sprinkled over with seasalt and garnished with radishes, pomegranates, lemons, fragrant herbs, asafoetida and ginger."[59]

Susruta describes seven types of meat dishes.[60] Four of these involve a frying operation: (a) sour meat cooked in ghee, curd, sour rice gruel, acid fruits, and pungent and aromatic constituents; (b) bharjita or fried meat; (c) pratapta, meat roasted over a charcoal fire while basting with ghee; and (d) vesavara, ground meat, meant for stuffing, which was first cooked with ghee, molasses, black pepper and ginger. In south India, fried meat at about the same period was called pori-kari, and meat fried after spicing the pieces was tallita-kari. Curry is the Anglicised form of the Tamil word kari.

The *Manasallosa* of the twelfth century AD describes a variety of fried meat dishes.[57] Frequently the meat was first shaped to resemble some natural form. Sheep mutton, and even liver, was carved in the globular shape of areca nuts (*Areca catechu*), or plums (the Indian jambu, *Syzgium cumini*, earlier called *Eugenia jambolana*), or amla (the Indian gooseberry, *Emblica officianalis*). These were sometimes first roasted and then fried with spices, or first fried with pulse paste and spices before marinating them in some sour fruit juice, or fried with spices and then boiled with mixed vegetables. Bhadritaka was the kabab of today, first roasted with spices and sometimes fried thereafter, and vattimaka were fried ground meat balls in gravy. Brinjals (aubergines, egg plant) were stuffed, as they still are today, with spiced ground meat, and then fried to yield purabhattaka.

The *Vedas* themselves list 250 animals, of which 50 were deemed fit for sacrifice,[61] and by implication edible. Later literature unfolds what these might have been, the more exotic being the deer, jackal, elephant, wild bear, monkey, tortoise, iguana, alligator, crab, pigeon, partridge and "peculiar mice that lived in the fields near rivers."[57] Charaka noted a large omelette, ursya pupalika, made of crocodile eggs and rice flour and cooked in ghee, which was recommended as an aphrodisiac!

An ancient recipe: Nearly 2400 years ago, Kautilya noted the quantities of ingredients that a shop selling cooked meat would require.[52] For 20 palas (466 grams) of fresh meat, one kuduba (256 g) of oil, one pala (23 g) of salt, one-fifth of a pala (5 g) of pungent spices, and two-thirds of a kuduba (171 g) of curds were called for.

Frying in the Cooking Ethos

Hindu food taxonomy: While cooking everywhere seeks to convert potentially edible material into palatable form, in the Hindu ethos both ritual purity and auspiciousness are added weighty considerations.[51] Cooking can occur without the use of fire, and of course on the fire. The tabular statement below shows the kinds of cooking gradations once laid down and that now operate, howsoever subconsciously, in the preparation of food:

1. *Cooking without fire*
   - 1.1 With water and/or manual techniques
   - 1.2 With milk products
   - 1.3 With air and sun

2. *Cooking with fire*
   - 2.1 With ghee
     - (a) Using anna (grains)
     - (b) Using no anna, but only phala
       - —using only milk and its products
       - —using fruit
   - 2.2 Without ghee

Anna include all materials raised with the help of the plough, whether cereals, pulses or oilseeds.[62] Phala by contrast are those that grow on their own, such as fruit, vegetables, roots and milk. This distinction is of great ritual importance, since those who give up worldly life are expected to eat only the latter, and so are ordinary people who are on vows to fast, or on ceremonial occasions. Milk and ghee have a special place, both being ritually pure and also auspicious. Milk is believed to have already been boiled by Indra since it emerges hot from the cow.[63] Ghee has been purified by the ordeal of fire, and indeed purifies anything that it touches.[51]

Thus washing vegetables with water, or soaking pulses, besides operations like peeling, cutting, sifting and grinding, all fall under the broader

orbit of cooking without fire. So does mixing fruits with milk in the cold to make a ritual panchamrita (a five-item fruit salad), or say cucumber with curds to give a raita. Cooking with air and sun embraces procedures such as dehydration, drying and pickling. Under cooking with fire, the major category is cooking with ghee. Cooking without ghee will include the boiling of rice or pulses, or even the roasting of a chapati.

Ritual food concepts: The major food categories are distinguished in the orthodox belief.[62] Kachcha foods are everyday foods like the chapati, rice and dhal. These foods are both exclusive and ritually pure, and strict rules govern their preparation. The cook must have bathed and then donned clean clothes, leaving his body bare. Once cooking has started, he cannot leave the restricted domestic cooking area till it is done. Kachcha foods are meant for domestic eating by the family within the eating area, usually adjacent to the kitchen.

Pakka foods are destined for wider consumption outside the domestic food area, and can be shared by those of higher and lower castes. The first contact of the food must be with ghee, after the latter has been added to the frying pan or deep frying vessel. Pakka foods are heavier to digest, less apt to become polluted and less likely to spoil. In the last analysis these foods can travel, and are less likely to cause disease than boiled foods.[64]

Ghee has a ritual significance therefore far greater than its use as a mere cooking medium. The slow acceptance in the Aryan tradition of vegetable oils for the purpose is therefore quite undestandable. A study of the Kanyakhubja, an orthodox community of Uttar Pradesh, showed that modern hydrogenated fat, vanaspati, has now attained the same ritual status as that of ghee![51]

In current practice, deep-fat frying, called talna, is done in a hemispherical kadhai of metal. The shape ensures that only a small volume of fat is required, and that it remains hot throughout the operation, while re-use is obviated because the fat is quickly used up. A speciality of Indian cooking is the baghaar. This is an operation that precedes the making of a palao or a meat curry, when the aroma and flavour of spices is extracted, usually one after the other, into hot fat, in which the dish is then cooked. Sometimes the baghaar say of cumin seeds in hot ghee or oil, will be made and poured over a cooked hot dhal as a 'finish' just before it is served.

Food and mood: The profound nature of a person influences his food desires: so says the *Bhagavad Gita*,[62] Sattvika natures, those of the reflective intellectual, contrast with rajasika temperaments which are dynamic and action-oriented, while tamasic natures are courageous and impatient of rituals and restraint. These three temperaments also demad foods of different kinds. A hot rajasika nature is helped to a more harmonious spirituality by eating foods that are classed as 'cold' (p. 172). A sattvika person who eats sattvik foods maintains his equable sattvik personality. The six seasons of the year affect bodily metabolism, and in turn the type

of food most suitable as a corrective. Emotional mood and situation also play their part in food choice. These relationships have been delightfully depicted in a sixteenth century AD work, the *Chandi Mangala* by Mukundrama Chakravarti written in Bengali.[65] In the course of this story, the meals given to various characters reflect both temperament and situation. Shiva is a tamasic character: he gets nothing cooked in ghee, which is a sattvik product, pure and luminous, but has to be content with food cooked in pungent mustard oil. Among a long list of food items, four may be mentioned: brinjals (aubergine) mixed with bitter neem leaves; for use as a pot-herb, pungent mustard leaves; as a pulse soup, lentils seasoned with lime juice and pieces of karanja (*Pongamia pinnata*) fruit; as a dessert, sour green mangoes cooked in lime juice. Vishnu is of a sattvika temperament: he does not ask for the usual starting sour item, nor for pot-herbs, but gets a tender gourd (parwal) browned in ghee, and a number of milk-based sweets like manda, khanda and nadu which are all round, and suggestive of the terrestrial globe of which he is lord. Two pregnant women of different social class in the story are served accordingly: the poor hunter's wife has no ghee, only roasted food, while the rich merchant's wife gets food with a tart flavour, rice but no tubers, and a variety of kitchen herbs. Finally the hunter himself, a professional rajasika, gets neither rice nor ghee to eat, only tubers, and no kitchen herbs.

5.2 Oils for Bodily Use

The Oil Bath

Part of the recommendation of the Indian system of health and medicine (see Section 6.1) is the importance of the daily oil bath.[65A] The *Susruta Samhita* recommends it both for adults and infants, stating that the oil applied gets absorbed into the blood and reaches every organ in the body in course of time, while particularly benefiting the skin, hair and eyes, and the muscles and joints, and eliminating wind or *vāta*. In practice, the whole body, or sometimes the head alone, in smeared with oil which is then rubbed in, left for an hour or more to be absorbed, and then followed with a vigorous hot bath. Kalidasa's play *Kumārasāmbhava* describes the oil bath of Parvati before her marriage to lord Shiva, the bath ending with an anointment with powdered tree bark and turmeric.

Scented and Medicated Oils

Usage: Parvati is in fact depicted as revelling in the use of scented and medicated oils, and finishing her ablutions by removing the oil from her skin with herbal juice and sandalwood paste.[66] In everyday life, certain days were considered ritually auspicious for oil baths, like Wednesdays and Saturdays: doing so on other days could attract unpleasant consequences.[5J] Fingers would be dipped in the oil receptacle, and seven drops let fall on the ground as a libation to the seven deities, thoughts of whom should fill the bather's mind while anointing himself. An oil bath was

prohibited on fast days.[5j] A pregnant woman, luxuriating in massaging her hair with scented oils till the seventh month of pregnancy, would desist thereafter for fear of encouraging the dread snake, Seshanaga.[22e] On Naraka Chaturdasi (see page 141), the first day of the 9-day Deepavali festival, people rise very early, rub themselves with perfumed oils from head to food, take a hot bath and then put on new clothes before making a light repast of fruits and sweets.[28d] The *Manasallosa* by King Someshwara lists among the 20 upabhogas, or pleasures of life, that of the bath.[57] This started with a massage using ointments, application of a wheat flour preparation to absorb grease from the skin and rubbing into the hair scented oils and sometimes scented turmeric, followed by a thorough washing off with hot water—topped with a refreshing quid of scented betel leaf for chewing! Later comes another of a king's pleasures, the anointing of the feet with unguents: in spring ghee, curds or cold milk, in the hot season butter, in the rainy season fat, marrow or buttermilk, in dry weather sandalwood water, and in the cold season, pure oil. Dressing the hair every day with vegetable oils that are naturally perfumed, such as fresh cold-drawn coconut or sesame oil, or artificially scented, is even now a natural part of the daily toilet of both men and women.

Manufacture: As early as the *Yajurveda*, in a long list of the classes of people who comprise Vedic society, are included "women who make scented oils",[31b] but whether this was by scenting already-pressed oils, or by pressing out a scented oil, remains tantalisingly open. Both methods are in use, and the great Emperor Akbar promoted the art by employing such artisans in the royal kharkhanas or manufactories, which included craftsmen of wide diversity.[35c] An 1840 description reads as follows: "The Natives never make use of distillation, but extract the essence by causing it to be absorbed by some of the purest oleaginous seeds, and then expressing these in a common mill, when the oil given out has all the scent of the flower which has been made use of".[35c] Layers of sesame seed wetted with water, alternating with layers of jasmine flowers, were covered over with a cloth and left for 12 to 18 hours, after which the seed was crushed to yield scented oil.[35c] This is still carried out in Kanpur and Kanauj: the sesame seed is dehusked, three parts of flowers to one of seed are used, the flowers are changed every day, and a very small ghani is used with very slow crushing so that no heat is developed (Plate 15). Even today jasmine is extracted using fat through the process of enfleurage in Europe. The traditional steam distillation process in India employs a cauldron placed on the fire; the steam is condensed in a coil, and passes into a copper vessel kept cool, where the oily layer that collects is skimmed off. Sandalwood and lemon grass have long been so treated to yield their distinctive perfumes.[35c]

Perfumed and medicated oils are also made by steeping the ingredients in the oil. The seed oil of kapittha (*Limonia acidissima*), impregnated with its own rind and pulp, enjoyed a high reputation.[20l] Two other recipes may be given.[67] Bhringaraj taila is made by boiling together four parts of

sesame oil with 16 parts of the juice of *Eclipta prostrata* (bhangra) and one part each of *Calotropis gigantea* (akra), triphala (an equal mixture of the three myrobalans, namely *Terminalia chebula*, *T. belerica* and *Emblica officinalis*), and *Ichnocarpus frutescens* (sarira). Making the well-known Brahmi taila is more elaborate. Boil with 18 kg of water the following: 1.5 kg of brahmi (*Centella asiatica*), 125 g of the roots of danti (*Baliospermum montanum*), 125 g of the turpeth root (*Operculina turpethum*), 85 g of the fruit pulp of amaltas (*Cassia fistula*), one kg of amla (*Emblica officianalis*), 31 g of black pepper, and 62 g of vidanga (*Embelia ribes*). Reduce volume to a fourth, strain, add the extract of 10 kg of sesame oil, and boil over a slow fire. Add to the mass a macerated mixture of 62 g each of *kapur kachri* (*Hedychium spicatum*), zedoary (*Curcuma zedoary*), sandalwood powder and priyanger (*Prunus mahaleb*) and 124 g of the roots of the poppy plant. Boil down till all water has evaporated. and strain the oil. Such medicated oils are now frequently marketed commercially under various brand names. So are medicated toothpastes with neem and karanja oils.

Coconut, sesame and castor oils have pride of place for dressing the hair. Somewhat exotic oils stated to promote hair growth are those of baheda (*Terminalia belerica*[20a]) and teak[20j] seeds. Kusum oil, from the seeds of *Schleichera oleosa*, was considered "an efficient agent for cleaning and promoting the growth of the hair, and is reputed to be the original macassar oil."[35d] Antimacassar cloths were doubtless devised in Europe to prevent the soiling of sofa backs from well-oiled heads of hair! Safflower oil was also said to be an ingredient of compounded macassar hair oils.[35e]

For keeping hair dark, or darkening the hair, oils from the seeds of neem,[68] thumba (*Citrullus colocynthis*[20k]) and somraji (*Vernonia anthelmintica*)[20l] were prescribed. As a carrier of hair dyes, sesame oil is mentioned in the Bower manuscript dated about 400 AD,[23] and again in the *Astangahrdya* of Vaghbhata the Second, dated about 850 AD. As dyes,[66,67] the following materials were heated with the oil: curry leaves (*Murraya koenigii*), pieces of amla fruit (*Emblica officianalis*), red shoeflower (*Hibiscus rosa-sinensis*), chebulic myrobalan fruits (*Terminalia chebula*) and leaves of bhangra (*Eclipta prostrata*, with sometimes iron filings added to give a deep black shade). To get a red shade, leaves of the henna (*Lawsonia inermis*) were extracted with oil.

Soaps

Detergents employed: Though knowledge of soap making in India is not recent, soap was never till modern times a detergent of any great importance. Natural materials were everywhere preferred, two in particular being very widely used. One was the dried fleshy berry of the soap-nut or ritha (*Sapindus emarginatus*), which was everywhere available commercially.[35d] It contains a saponin which lowers surface tension, and is used not only on the skin, but for washing fine woollen Kashmiri shawls, silk garments, gold and silver plate, and jewels tarnished by use. The other was the fruit pod of *Acacia rugata*, called shikakai in south India, which on drying

yields a greenish powder with surfactant action, which is greatly valued in washing body and hair, especially after they have been oiled. A somewhat unusual material is mahua oilcake: the toxic saponin present both washes the hair and removes lice!

Powders of various pulses are also in common use, especially those of *Cicer arietinum*, the chick-pea or Bengal gram, called besan. It is used as a paste for cleaning the hands or skin, sometimes with added turmeric powder, honey with lime juice, or sandalwood powder.[66] The Chinese traveller I-tsing, who was in India between 671 and 695 AD as a Buddhist pilgrim and student, describes how after a meal, perfumed paste was supplied to cleanse the hands.[25e] And nearly five centuries later, King Someshwara records how, after anointing the feet with oil, the powder of masura pulse (*Lens esculenta*) mixed with turmeric was applied to remove the grease, followed by washing with water.[57] An equal mixture of the powders of Bengal gram, green gram (*Phaseolus aureus*) and fenugreek seeds, with added perfume. is another skin-cleansing paste.[66] Sandalwood paste is itself commonly used, sometimes combined with turmeric to cleanse the skin and act as a depilatory.

Natural clays, especially those which are slightly alkaline and are discussed below, are the commonest of washing powders all over the country. Sometimes they are combined with the ashes from wood or charcoal fires that are always available from the kitchen and are alkaline and detergent.

Soap-making in India: "The art of soap-making", Watt remarks, "had been known and practised from a remote antiquity (in India). . . Crude soap is. . . largely manufactured and sold in every village to be employed by washermen and dyers."[35f] Use of washing and toilet soaps as consumer items in India came in however with the industrialisation of Britain. In 1876-77, soaps worth Rs. 0.33 million were imported into India and 30 years later, this had gone up ten-fold to Rs. 3.22 million.[35f] In the same period, commercial soap-making commenced in India with the setting up in 1897 of the North West Soap Co. in Meerut by a British enterprise.[69a] The Indian industry started with small units, and the organised large-scale sector followed. In 1920-21 imports of soap accounted for Rs. 20 million, but 20 years later, this had dropped to just Rs. 1.8 million. Soon after Independence in 1947, imports were banned. In 1951 some 250,000 tonnes of soap were being produced, about 70 per cent of which was in the large sector. In 1969-70 soap was being exported to the tune of Rs. 13.6 million, with imports (of a few speciality items) standing at just Rs. 0.36 million.[69a] Some 250,000 thousand tonnes of toilet soap and 650,000 tonnes of synthetic detergents were produced in 1985-86.[69A]

Sodium and potassium carbonates have been traditional items of manufacture in India. Sodium carbonate is made by a process of calcination called barilla from certain saltworts found in the arid areas of Punjab and Gujarat, like *Haloxylon recurrum*, *Salsola foetida* and *Suaeda fruticosa*.[35g] In hemispherical pits are placed inverted pots with perforations

which are initially plugged with sticks. Dried plants are burnt in the pits, and the liquid is allowed to run through the holes into the pots, which on cooling yield pure khar sajji, while the ashes in the pit represent a material of inferior quality. Potassium carbonate, yavashara in Sanskrit and sarjika or jon-khar in Hindi, is very widely manufactured as the ash from a variety of plant leaves.[35h] These include several oleaginous materials, *Pongamia pinnata* (karanja), *Shorea robusta* (sal), *Calotropis gigantea* (akra) and *Butea monosperma* (palas). The salt is very widely used in the arts, sciences and medicine, and is hydrolysed to give caustic potash. A third source of alkaline salts is sajji matti (literally alkaline earth) or reh, an efflorescence that occurs on the surface of the ground in many parts of India, especially in arid and desert areas.[35i] The soil is simply washed to yield the salt, which is a mixture of sodium carbonate (sajji), sodium sulphate (khari) and sodium chloride (namak), with either the carbonate or the sulphate predominating in specific areas. Blocks of pure sodium carbonate are mined from the Lonar lake in Berar, Madhya Pradesh. Reh is put to a myriad uses; among these is the preparation of country soap, often along with burnt lime (calcium oxide), by boiling them in aqueous solution with oil.

The *Ain-i-Akbari* describes a scented soap, opatna, and a liquid soap, ghasul.[26b] In making the first, the ingredients are pounded, sifted and boiled "slowly in rose water: when it has become less moist, let it dry". The other also uses various scented materials mixed with rose water. These products are probably hand perfumers with some cleansing action, rather than true soap.

Recent trends: Production of sophisticated toilet, bar, washing and liquid soaps using modern machinery is now an enormous industry in India. It will not be dealt with here.

Distinctive to India is the preparation of soaps in the small manufacturing sector from unique oils like neem, karanja, khakan and pisa. These frequently have a deep colour and bad odour. The full-boiled process is not suitable since overhead costs are high for the small quantities made. Straight semi-boiled or cold processing is not possible because of poor oil quality. Accordingly a combined full-boiled and semi-boiled technique has been evolved, and is described here for neem oil.[70,71] Neem oil (or any other coloured and odorescent oil) is first saponified and then grained to remove colour and odour; this grained soap becomes the stock to which other pale-coloured oils and caustic are added to complete the processing by semi-boiling.

Neem oil in a pan is placed on the fire and a measured quantity of 20° to 25° Bé dye is addded with constant stirring. After completion, about 4 to 5 per cent salt (on oil basis) is added to cause the soap to break, and the mass is stirred for some time, cooled and allowed to settle. The very dark lye is drawn off. Especially when the free acidity of the oil has been high, saponification of oil may not be complete because of too rapid a neutralisation. Accordingly some water and caustic are added, and the whole is

boiled and stirred, and settled by adding some salt if necessary. The saponification and graining operations are repeated, using the second alkali-rich lye for the first graining of the next batch. The grained neem soap is then taken in a fresh soap pan and boiled with a little water, after which the other oils in the blend and the caustic (30° Bé) are added alternately. When the operation is complete, the mass is tested for free alkali or free oil; colour and perfume is then added, after which the molten mass is poured into moulding frames.

With 50 kg of neem oil, the following materials will give a red carbolic soap: coconut oil 10 kg, mahua oil 30 kg, sodium silicate 15 kg, and cresylic acid 4 kg.[70] For a green household soap, cresylic acid (which imparts the red colour) is replaced by a green dye, and rosin 5 kg and perfume are also used. For a yellow washing soap, no dye is employed in the formulation described for green soap. In toilet soaps, rosin is substituted by mahua oil.

The Khadi and Village Industries Commission (KVIC) has been particularly active in promoting the production of such soaps, in which it is claimed that the antibacterial substances of neem (margosa) and karanja oils are not completely lost.[72] Since toilet soap manufacture requires stringent specifications, these are made in special units which employ ribbons or chips of crutched soap that have been produced elsewhere in simple soap pans. A number of such medicated soaps made by the KVIC and by private manufacturers are on the market.

Sophisticated soap-making using non-traditional oils: Means of upgrading various Indian non-traditional oils are dealt with in some detail at various points in Chapters 7 to 12, but techniques for their use in soap-making may briefly be brought together here.[73] The odorescent sulphur compounds in neem yield to vacuum distillation. but the bitters are left behind; the the residue can be used in laundry soap manufacture, and the fatty acids obtained by splitting and distillation are of good enough quality even for toilet soap manufacture. The same principle of vacuum distillation of the oil is also effective in removing the phenolics in karanja oil, and the lipid associates in pisa fat. Khakhan fat requires a vacuum steam stripping to remove all the odour and part of the colour, followed by splitting and distillation to yield fatty acids of excellent quality. Both kusum and nahor fats are treated by straight splitting and distillation to yield fatty acids of high quality. The non-glycerides in kusum oil are first selectively hydrolysed with zinc oxide and sodium hydrosulphite to give a mixture of fatty acids and of the triglycerides which, after removal of zinc with sulphuric acid, can be utilised as a whole in soap-making. Sal fat only requires bleaching of its green colour using phosphoric acid, and mahua fat needs no special upgrading for use in the soap kettle.

5.3 Other Outlets for Indian Oils

Body anointing and religious outlets, which are somewhat distinctive to India, and soap-making, have just been discussed. There are a few other

outlets for vegetable oils in India which may be considered against a traditional background.

Illuminants

All vegetable oils have been employed extensively in the past to provide fuel for wick-lamps. Of these coconut and castor oils have had pride of place, it being claimed for castor oil that it yielded a cooler, brighter and steadier flame than any other. Mahua oil was in use as an illuminant in southern temples and among Indian tribals. With the advent first of cheap kerosene, and then of even cheaper electric power, the use of expensive vegetable oils for burning has been greatly reduced, though still practised in the rural interior.

Lubricants

For any machinery with moving parts, like cart wheels, ghanis, pulleys placed above wells and the like, the traditional lubricant oil of choice was castor oil for its excellent 'oiliness' under pressure.[69b] This use was extended to the railways when these spread all over India after about 1850, and indeed castor oil was considered *non-pareil* for the purpose—till displaced by mineral oil products after the First World War. More sophisticated lubricants and brake fluids based on castor oil and hydrogenated castor oil continue on the market. Other oils employed as lubricants were those of the rape-mustard family (colza oil, blown rape oil) and coconut oil.

Paints

Surface coatings have a long history in India by way of painted pottery of various kinds that started with the Indus Valley, and indeed even earlier.[69c] The *Yuktikalpataru* dated about 500 AD has recipes for painting boats to protect them from sea water. The frescoes of Ajanta of about the same time used pigments in a tempera medium, while the still flourishing enamel work of Rajasthan is of brilliant colour quality. Oil-bound paints were however not favoured, the preference being for natural glossy coatings like shellac, and for varnishes made from several natural resins such as black dammar from *Canarium strictum*, white dammar from dhupa (*Vateria indica*), gum arabic and gum ghati from *Acacia* species, and kino from palas (*Butea monosperma*). These were used not only to treat and embellish wooden articles, but as components of starch-based cloth finishes and as ingredients of the ubiquitous burnt-lime washes so common all over India, in which the resin ensures better adhesion to wall surfaces.

The first modern factory to make ready-mixed oil paints was the Shalimar Paint, Colour and Varnish Co. Ltd., which was established in 1902 in Howrah, Calcutta.[69c] Between 1919 and 1923, six new factories were established in various parts of India, and by 1938 about 60 per cent of the needs of the country, or some 25,000 tonnes of standard paints, were being manufactured. This went up to some 56,000 tonnes in 1945, and by 1963 to 86,000 tonnes. Two decades later, in 1983-84, there were 18

units in the organised sector making about 112,000 tonnes of various types of paints, and another 900 small-scale units making over 200,000 tonnes of mostly simple ready-mixed formulations.[74,75] Exports in the same year, mostly to the USSR, were worth Rs. 280 million.

Leather Manufacture

This is an industry of antiquity, meeting the needs of civilian and warrior alike, and oils play a part in several of the operations even to this day.[69d] Leathers tanned with vegetable tanning agents like myrobalans are folded while wet and subjected to hydraulic pressure; to ensure that evaporation of water occurs only from the fleshy surface, the grain surface is treated with vegetable oils before the pressed skins are spread out to dry. Heavy leathers that have been vegetable-tanned are 'stuffed' with cod liver oil, fish oil or tallow to increase their tensile strength, and render them soft, pliable and waterproof; the process is called currying, and is carried out by hand several times. Sole leathers, after tanning and bleaching, are finished by sponging the grain surface with fish oil or castor oil, followed by heavy rolling, conditioning and repetition of these operations twice or thrice. Finally the goods are given a coat of wax and soap, polished, and rolled to yield a compressed leather for use as soles. Chamois leather is made from split sheep skin which is hammered in with wooden mallets, sprinkled with fish oil, and then spread out for the oil to 'dry' by oxidation. This is repeated several times.[69d]

Dyeing

The dyeing operations connected with India's enormous variety of textiles make use of vegetable oils at many points. A fragment of woven cotton cloth found at Harappa was dyed with madder,[76a] revealing knowledge of the technique of mordant dyeing by which the dye is rendered both even and fast. Indian dyed goods were long famous. In the translation of the Bible in the fourth century AD, St. Jerome likened the lasting value of wisdom to the permanence of the dyed colours of India.[76b] The mordant process, in which the cloth is first prepared with a mordant and then immersed in a dye, or the mordant and the dye are applied to the cloth either by block or by brush, needs no oil, nor does block printing.[76a] The resist process however involves cooking the cloth with wax, oil, resin, clay or other resist, these portions remaining undyed when the cloth is later immersed in the colour solution. Yet another form of resist dyeing is to apply to the material a thick pigment in the medium of a boiled oil called roghan (see below), thus producing patterns which appear to be encrusted on the fabric; if the pigment is a gold powder, the effect is that of raised jewellery.[75A]

In typical resist process dyeing, the cloth is thoroughly soaked in an alkaline medium (sometimes water with camel dung), then washed and dried.[76c] It is then soaked in water containing a caustic alkali and castor oil and left to dry. Such cloth is ready to take printing using blocks or

hand painting, the dye used being thickened with tamarind kernel flour. This is a material which is also used for calico printing, to prepare paper strips for painting, and to achieve lacquering on wood or metal over a fire.[76d] In dyeing with the root dye of *Morinda citrifolia*, called *al*, the cloth is first steeped in water containing a little sesame oil or castor oil (or even powdered castor seeds) and an alkali material (alkaline earth or sheep dung) for long periods of several days (all at once or intermittently), and then washed to a silk-like lustre.[20m] The dye and alum are boiled in water, and the cloth held in it till the required depth of red is achieved. Both starchy materials and gums (that of the kapittha, *Limonia acidissima*, is common and popular) are employed to thicken both water-soluble and suspended pigments and to prevent them from diffusing.[20l] Tie-and-dye operations are similar, the cotton thread, or the cloth itself, being ingeniously treated with oil or waxy materials to resist dye penetration and yield coloured patterns of great beauty on the final cloth. Examples of this are fabrics known as patola, bandhana and ikat. In the murals of the famous Ajanta caves which were created mostly during the fifth and the sixth centuries AD, women wearing ikat cloth have been identified: these could be the telia rumal (oily cloth) still produced in the area, the word telia pointing to the use of oil (tel) during the resist dyeing.

The roghan referred to is a bodied oil, created from safflower oil during the process of extraction from seed using intense dry heat (page 239). It is also traditionally made from *Carthamus oxyacantha* or polli oil by heating the latter to high temperatures in the open for 12 hours with the evolution of immense volumes of white vapour, after which the very hot mass is thrown into cold water held in shallow trays to give a jelly-like product.[35e] Roghan is a polymeric, water-repellent material used in resist dyeing and in preparing the so-called Afridi wax cloth, in which a thick paint of roghan and pigment was applied in designs on cloth using an iron stylus. Roghan was also employed to impregnate and preserve leather articles like buckets, ropes and harness that are frequently exposed to the action of water.[35e]

Oils were also used in the traditional preparation of vegetable dyes. Safflower florets collected for dye preparation are rubbed with some sesame oil, perhaps to keep them succulent.[35e] A similar treatment is given to the powdery pubescence that constitutes the kamala dye (*Mallotus philippinensis*).[35j] The leaves of henna or mendhi (*Lawsonia inermis*) are dried and sifted, and a little rape-mustard oil added before reducing the mass to powder.[35k] The roots of *Morinda citrifolia*, called al or bartundi, are also ground to a powder using a little sesame oil.[20m] In preparing indigo from the plant a century ago, the stems were cut down, steeped in water, and then vigorously beaten in a cistern under water into a lather: "then they cast into it a little oil-olive. . . and as soon as the said oil is thrown in, the latter separates into two parts" (Pomet, 1694).[35l] These settlings constituted the indigo dye.

CHAPTER 6

Oilseed Plants in Indian Medicine

6.1 Traditional Indian Medicine

Principles

Medical authorities: The mythological churning of the ocean (Section 4.1) brought forth *inter alia* the father of Indian medicine, Dhanavantari, bearing aloft the pot of amrita, the immortal nectar. To him is attributed the medical science embodied in the *Atharvaveda*, one of the four Vedas compiled between 1500 and 1000 BC, from which the science of Indian medicine, called ayurveda, is derived. About the sixth century BC Susruta is believed to have flourished, essentially as a surgeon. His original work is lost, and what we have as the *Susruta Samhita* is a much later redaction or commentary of about 400 AD. This however is believed to preserve a large amount of the original text through verbal memory. Susruta describes inflammation of various types, accidental wounds, burns, fractures and many major abdominal operations. He utilised 101 kinds of blunt instruments and 21 kinds of sharp instruments and placed shalya or surgery as the highest in value for relieving human suffering.[77b,77c,78a]

Of greater importance to the present purpose is the *Charaka Samhita.*[53] Charaka again is supposed to have lived in the sixth century BC; the present recension may be about eight centuries later, though it is clear that a great deal of the original is preserved. This is supported by the evidence of the Bower manuscript, a bundle of inscribed birch-bark strips written by certain Buddhist monks about 300 to 400 AD, which repeats large stretches of the *Charaka Samhita.*[77c]

The basis of Hindu medicine: Ayurveda sought to achieve a harmony between mental health, through injunctions for an ethical life, and positive physical health. The latter is sought to be achieved by prevention of and resistance to the entry of disease through a dietary regimen, physical exercise and bodily hygiene, and correction against disease when this appeared.[78a] Disease was essentially considered as an upset in the balance of body humours.[79] The five states of matter, earth, water, fire, air and sky, combined in the body to engender three dhatus, which are kapha (earth

plus water), pitha (fire) and vatha (air plus sky). These tridhatus are expressive of the trigunas, which are the three attributes of matter. Kapha represents the guna termed tamas, which is associated with courage and forbearance. Pitha is associated with sattvika, and is reflected in intelligence, and analytical clarity of thought and action. Vatha is teamed with the guna called rajas, the dynamic principle of impulsiveness and hasty action. Wrong foods, in any particular individual with his own natural mental colouration, can upset the normal equilibrium of the three dhatus. The resulting imbalance transforms them into doshas, harmful elements which show up in ill-health and disease. Bound up with these beliefs were the ideas of foods that are 'hot' and others that are 'cold' in relation to their effects on body and mind. Thus in the Ayurvedic concept, ghee is a cold food, but both sesame and mustard oils are hot.[80] Yet while these concepts dominated, the microbial origin of disease is more than once hinted at. Susruta says: "All forms of leprosy, and some skin diseases, are due not only to derangements of vayu, pittha and kapha, but also to microbes".[77b] And again: "Various diseases, leprosy, fever, pulmonary consumption and ophthalmia, and diseases borne by air and water, are usually capable of transmission from one man to another".[77b]

Some quotations from Charaka and Susruta will serve to indicate the basis and approach of ayurveda to disease and its cure:[78a]

1) "Life is spoken of as the union of the body, senses, mind and spirit. The body, mind and spirit are, as it were, the tripod"
2) "Virtues of cleaning the teeth, scraping the tongue, cleaning the mouth, massage and bathing, wearing of clean apparel, trimming of hair, beard and nails, frequent ablution of the excretory orifices, must all be emphasised"
3) "An excess or surfeit of food is markedly harmful unless the gastric fire is increased by hard exercise"
4) "Medicine is that, which being well administered, becomes an equaliser of increased and diminished elements at the same time. . . for it is only with a view to help maintain the balance of the elements that the intelligent will make use of a balanced diet"
5) "Medicine is of two kinds: one kind is promotive of vigour in the healthy, the other is destructive of disease in the ailing"
6) "A single drug may have many applications owing to its diverse actions"
7) "The physician will try to cure the diseases which are curable; seek palliative measures where this is the only remedy that can be offered; and give up a case which is beyond all medical treatment, and mostly, those that are of more than a year's standing"
8) "The physician must take into consideration that drugs differ with respect to land, season, source, flavour, taste, potency, post-digestive effects and specifications, and also that men differ with respect to their body, constitution, age, vitality, gastric fire, morbid tendency, productivities, homologation and state of the disease"

9) "It is better to take a portion of a mild medication repeatedly as it is attended with only slight discomfort and no risk, than to take a very strong medication which is attended with immediate danger to life"
10) "He who practises medicine neither for gain nor for gratification of the senses, but moved by compassion for creatures, surpasses all"
11) "For a learned man, there are only two methods of examination: direct observation and inference"
12) "Of all types of evidence, that which we observe with the eye is the best"
13) "The physician should palpate the patient's entire body with his hands. All abnormalities should be noted"
14) "Those who are mistaken in the diagnosis of disease will also be misled in deciding the line of treatment"
15) "Discussion with a person of the same branch of science is indeed what makes for the increase of knowledge and happiness. It contributes towards the clarity of understanding, dispels doubts, and confirms the ideas of those who have no doubts. It enables one to learn new things in the course of discussion".

Aids to diagnosis: Just two may be described.[78a] In the *taila bindu pariksha* (oil-drop test), a drop of sesame oil is placed gently, using a piece of hay, on the surface of urine in a utensil. If the oil spreads over the surface, the disease is curable; if it remains suspended, the disease is difficult to cure; if it settles at the bottom, the disease is incurable. The second test, perhaps the first flame photometer, is in regard to poisons in food: part of the food is to be thrown by the physician into the fire, and the colour of the flame, "variegated like the feathers of the peacock", and the smell of the burning, is to be observed to indicate the persence of poisons.

Domestic Healing with Oil-bearing Materials

Domestic practices: Every Indian home is the repository of simple treatments, derived from 'grandmother', using materials readily available at hand, or even prepared and put away against use. Many of these are of course based on ayurvedic injunctions, both sharpened and softened by practice and experience into home remedies. Some of these remedies based on oil-bearing materials are outlined below in an order convenient for domestic use, rather than according to the source of material.[66]

Intestinal problems: As a regular purgative, a little castor oil in warm milk every night is recommended. For children, a soft betel stalk or cotton wick is dipped in castor oil and inserted in the anus. An itchy skin can be massaged with roasted pomegranate skin grated in an oily base. For worms, the powdered seeds of *Cleome viscosa* (hurhur) with sugar is effective. For intestinal works, ground neem leaves or their juice, or neem flowers, or neem oil, are a prophylactic. Even the cysts of intestinal flukes

are eliminated by a monthly regimen of neem juice in castor oil. For jaundice, a decoction of the leaves or flowers of neem mixed with white radish, leaves of the simul (*Bombax ceiba*), and red hibiscus flowers is concentrated and given thrice a day. Mango kernels ground into a paste serve as pills for piles.

Colds, fevers and respiratory illness: For a cold, an inhalation of a decoction of neem leaves, turmeric powder and leaves of *Vitex negundo* (nirgundi) is followed by a poultice of hot betel leaves (*Piper betle*) coated with ghee. A hot linseed decoction is prescribed for chronic cold, cough and congestion, and to stimulate urination in chronic diarrhoea and dysentery. In measles, chickenpox and mumps, pasting with a neem leaf poultice containing turmeric, and bathing in neem leaf water, is recommended. External massage with ghee, or with lemon juice in hot mustard oil, is favoured in a sore throat or breathing difficulty.

Eyes, ears and mouth: For the eyes, a few drops of castor oil, or of the oil medicated with the lampblack made from castor oil (to which a trace of camphor is added), or that made from ghee, is routinely recommended. Swollen eyes can be fomented with a poultice of mashed rice and castor oil, or with clear coconut water. Neem oil drops in the ears are routinely used as a prophylactic. Sometimes the root of kapittha (*Limonia acidissima*) or of the seeds of *Strychnos nux-vomica* are dipped in neem oil and then set alight: the oil that oozes out is highly regarded for ear problems. Chewing neem twigs before using them as a toothbrush will prevent toothaches. For a toothache, mango leaves are soaked for months in brine, and the extract concentrated: a few drops are held in place with a cotton wad.

Skin and hair: To avoid skin infections, routine drinking of coconut milk, or an infusion of neem leaves or green mangoes is recommended. For boils, there are a number of remedies: neem leaf paste, ghee with ash, roasted betel leaves coated with castor oil, coconut oil with wheat flour, coconut milk with powdered cumin seeds, and pastes of mango or neem barks. The corrosive fresh exudate of akra (*Calotropis gigantea*), if just spotted on a boil, will burst it and bring relief. All parts of the mahua tree are effective against ulcers. So is a paste of the barks of the banyan and peepal trees in coconut milk. For burns also there are several home remedies: a paste of burnt tamarind leaves in sesame oil; a poultice of neem leaves soaked in any oil; a decoction of neem bark; and coconut oil medicated with hariali glass (*Cyanodon dactylon*) to which the resin of *Celastrus paniculatus* (malkanguni) has been added. Whitlows call for a castor oil-lime water emulsion, and corns for pieces of liquorice root in mustard or sesame oil.

For eczema, undi oil (*Calophyllum inophyllum*) or a decoction of its bark, coconut oil medicated with garlic segments, neem leaf extract, and sesame oilcake are all prescribed. For acne, the blackheads are touched with a paste of turmeric ground with some mustard seeds, and left overnight. To remove lice, coconut oil with a pinch of camphor, or seeds of

the sitaphal (*Annona squamosa*) ground to a paste, are applied all over the skull for a few hours. Hibiscus leaves, which are very mucilaginous, constitute an excellent shampoo for the hair.

Bleeding, swelling and aches: Astringent styptics to arrest bleeding occur abundantly in the mango: its charred seeds, leaves and bark are used, or their decoction, or their juices for fast action. For swelling and pain, a paste of turmeric, quicklime and garlic in warm mustard oil, or of camphor or onion juice in the same oil, should be well rubbed in. Even for an excruciating headache, a mustard seed poultice, softened by adding cream and salt, will yield a response. Black sesame seeds, soaked overnight in water and drunk next morning, are an effective prophylaxis against frequent joint pains.

Urinary and sexual matters: When urine retention occurs, a paste of camphor and sandalwood in warm mustard oil is massaged over the abdomen. Tender mango leaves are dried, powdered and stored for regular use by diabetics. As aphrodisiacs, sesame seeds have a long-standing reputation, and the flowers of drumsticks and coconut are given to newlyweds in south India. Sesame seeds are believed to carry hormonal principles. Eaten as balls made with thickened jaggery syrup, called laddus, they bring on puberty in young girls, and are avoided in early pregnancy for fear of inducing an abortion. When birth approaches, an easy confinement is assured through pills of the seeds made with honey, powdered mahua root and powdered citrus (lime) root. Laddus of a different composition are given after confinement to strengthen the mother: these are made of copra shavings, poppy seeds, pieces of dry ginger, and seeds of various gourds like the cucumber, pumpkin and squash. Traditional galactogogues to increase the flow of breast milk are fenugreek and garlic, but sesame laddus and a decoction of cottonseeds are also used.

Longevity and good general health: Almonds have a very high reputation in Indian medicine for conferring vigour, and are taken soaked, blanched or blended in milk. A mixture of the seeds of four gourds, called giriya, is considered useful to enhance the functioning of the brain. "Cooling the system" has a conceptual place in Indian medicine, and a decoction of kokum fruit (*Garcinia indica*) is one way of doing so. Another is to massage the body before a bath with medicated oils of various types: one is made by boiling coconut oil with dry amla fruit (*Emblica officinalis*), capsules of harir (*Terminalia chebula*), neem seeds, wild turmeric (*Curcuma aromatica*) and pepper seeds. Others have been described earlier (p. 163).

Traditional Curatives

Range of materials: Almost every part of every known plant or tree is used in some form or the other for curative purposes, and this includes the 67 oleaginous species that are treated in this book. Such lore from various recorded sources is succintly put together in tabular form.[20,67,67A,68,79,81] Table 5 lists oilseed-bearing plants from the three Groups A, B, and C, namely historical oilseeds, newer oilseeds, and byproduct oil-bearing

Table 5. Uses of oilseed plants in traditional Indian medicine: Groups A, B and C[59,67,69,79,81]

Group A. Historic oilseeds

A1. SESAME

Seeds: *Burns, scalds, boils, gout, piles* Poultice; *Dysentery, burning, piles, urinary disease* Infusion with liquorice root; *Piles* Pills of seed, turmeric, *Aegle marmelos* and jaggery; *Amenorrhoea, cough* Infusion of seeds with jaggery

Oil: *Skin diseases, hair* Medicated oils (see Text); *Burns* Blend with carron oil and lime water; *Earache* Ground with pickled asafoetida, ginger and rock salt, *Ear discharge* Extract with *Helicteres isora* fruit.

Leaves: *Diarrhoea, dysentery, gonorrhoea* Cold infusion with sugar; *Skin diseases* Leaf ash with sesame oil.

Stalks: *Belching* Extract with jaggery

Flowers: *Gonorrhoea* Infusion

A2. COTTONSEED

Seeds: *Burns* Poultice; *Abscesses* Paste of boiled seeds; *Inflamed testicles* Ground paste with ginger

Oil: *Headache* Massage

Leaves: *Rheumatism* Poultice

Capsules: *Ear discharge* Infusion, along with honey

Root bark: *Abortion* Decoction (internally)

A3. RAPE-MUSTARD

Seeds: *Emetic* Mixed with water; *Anorexia, indigestion* Ground with asafoetida, ginger, cumin seeds, rocksalt and butter-milk; *Goitre, Scrofula* Ground with butter-milk; *Neurolgia* Poultice

Oil: *Itch* Paste with garlic; *Pimples* Blend with sandal oil; *Swelling* Blend with onion juice; *Breasts* Ground with pomegranate, massage; *Dandruff* Mixed with juice of *Peganum harmala*, massage; *Lice* Mixed with *Celastrus paniculatus* bark; *Scrofula* Ground with *Citrus colocynthis* pulp, or Medicated with *Cassia tora* roots, *Eclipta prostata* juice and red lead

A4. COCONUT

Meat: *Tapeworms* Grated with castor oil

Oil: *Hair tonic and dye* Ground with *Eclipta prostata* leaves; *Burns* Paste with ash of coconut meat

Flowers: *Diabetes* Mixed with curds

Coconut water: *Fainting* Drink with barley flour and sugar

Burnt shell: *Ringworm* Oily condensate on stone cup placed over red-hot shell

A5. LINSEED

Seed: *Bronchitis* Hot infusion with liquorice root; *Copper poisoning* Cold infusion

A6. CASTOR

Seeds: *Abscess, gout, rheumatism* Poultice; *Sciatica* Ground with milk

Oil: *Eye inflammation* Cold oil: *Guinea worm abscess* Worm drawn out using scalding oil; *Flatulence* Mixed with extracted ginger

Leaves: *Rheumatic joints, eyes, piles, galactogogue* Hot poultice; *Guinea worm* Poultice with hot castor oil; *Inflamed breasts* Oiled leaves poultice; *Jaundice* Juice in milk; *Lumbago* Mixed spices, followed by leaf decoction; *Night blindness* Cooked in oil together with leaves of *Leptademia reticulata; Anaemia* Leaves of castor, *Emblica officianalis* and *Caesalpinia crista* with cloves, pepper and cumin

Flowers: *Laxative*

Roots: *Skin disease* Decoction; *Scrofula* Paste in rice-water with *Butea monosperma* roots; *Dysentery* In milk; *Heart disease* Decoction with potassium carbonate

A7. NIGER

Seeds: *Diuretic* Every morning

Oil: *Eye diseases* Drops

A8. SAFFLOWER

Seeds: *Uterus inflammation after childbirth* Poultice; *Ulcers* Paste

Flowers: *Measles* Hot decoction (drink)
Dye: *Purgative* Drink in milk

Group B. Newer oilseeds

B3. SUNFLOWER
Leaves: *Chest congestion* Cold decoction

Group C. By-product oilseeds

C4. TOBACCO
Leaves: *Boils, gumboils, rheumatic swellings, skin diseases, syphilitic nodes, hydrocele, strangulated hernia, tetanus* Poultice; *Dropsy, urine retention, muscle relaxant* Internally, as sedative and antispasmodic; *Strychnine poisoning* Infusion, as antidote; *Spleen enlargement* Ground with lime (externally); *Toothache* Wad; *Night blindness, conjunctivitis* Oil that condenses on smoking leaves in a hookah (external)
Stalk: *Laxative for children* Insert into anus

C7. JUTE
Leaves: Both species similar. *Dysentery, fever, dyspepsia* Infusion (cold, internally), with honey or turmeric or rice; *Abdominal obstruction* Ash of leaves with honey

C9. TEA
Leaves: *Chronic weakness, convalescence* Infusion as stimulant

materials. Table 6 includes oil-bearing plants from Groups D to G, and Table 7 the remaining plants from Groups H to K.

For convenience, the various parts of the plant are given in the same order, namely, seed, seed oil, leaves, stalks, and flowers; fruit, fruit pulp, rind, kernel, shell and capsule; wood, outer bark, gum, milky sap, inner bark and dye; and root and root bark.

In practice. these are rarely applied singly, being almost always compounded in various ways. Prescriptions come in both solid and liquid forms, which have various names. A decoction constitutes a kwath, and a churna is a powder; an aristha is a liquid tonic mix, an avleh is a soft, sweet halwa, and a pak a harder confection. A taila is a medicated oil, and examples of their preparation were given on p. 163 and p. 175. Formulations for a few other products follow.[67]

The famous *Triphala*, a kwath given as a general anthelmintic, is a decoction made from equal parts of three myrobalans: harada or harir, the chebulic myrobalan (*Terminalia chebula*), baheda, the beleric myrobalan (*T. belerica*), and amla, the emblic myrobalan (*Emblica officinalis*). To these are added baberang (*Embelia ribes*), the tubercles of nagarmotha (*Cyperus scariosus*), the herb musakani (*Merremia gangetica*) and the bark of shigru, the horseradish tree (*Moringa oleifera*). The decoction is administered with powdered long pepper, pippali. Another decoction is Patoladi kwath, which uses the triphala myrobalan trio just described, along with the leaves of *Trichosanthes dioica*, the bark of kurchi (*Holarrhena antidysenterica*), tubers of nagarmotha, root of liquorice, dry stems of gulancha (*Tinospora cordifolia*), leaves of vasa (*Adhatoda vasica*), bark of deodhar (*Cedrus deodara*) and black raisins. The third decoction, Darviadi kwath, has equal parts of various roots, barks, fruits and wood, and purple flowers of the akra (*Calotropis gigantea*),

Table 6. Uses of oilseed plants in traditional Indian medicine: Groups D, E, F and G[a]

Group D. Trees with oilseeds bearing oils with lipid associates

D1. NEEM

Oil: *Skin diseases of all kinds* (ulcers, itch, ringworm, erysipelas, scrofula; *Hair* (lice, darkening); *Ear* (deafness); *Mouth* (soft gums, angular stomatitis); *Intestinal worms*; *Piles* (external); *Contraception* (apply to vagina)

Leaves: *Boils, whitlows, ulcers, foetid wounds* Poultice, with added liquorice root, ghee and honey; *Earache, emetic sinus, dandruff* Decoction; *Urticaria, liver disorders* Decoction (internally); *Rheumatism* Extract with milk; *Leprosy* Powder leaflets (internal); *Piles* Paste with ghee; *Intestinal worms* Extract, with fried asafoetida and honey (internally); *Childbed fever* Juice

Stalks: *Diabetes* Decoction

Fruit: *Intestinal worms* As purgative; *Urinary afflictions, Piles* Unripe berries, or Ripe berry juice with jaggery on empty stomach

Bark: *Fever, nausea, skin problems* Paste

Inner bark: *Boils* Paste; *Eczema* Ash of bark; *Urticaria* Decoction drunk; *Mouth ulcers* Sucked; *Diabetes, jaundice* Decoction drunk

Root: *Toothache* Decoction; *Sinus* Juice

D2. KARANJA

Seeds: *Itch, rat bites* Paste; *Leprosy* Paste with bark of kurchi (*Holarrhena antidysenterica*); *Migraine* Boiled, with jaggery; *Bronchitis, asthma, whooping cough* Expectorants; *Eye complaints, corneal opacity* Salve, with flowers of palasa (*Butea monosperma*), in ghee

Oil: *Skin diseases, ringworm, eczema, itch, psoriasis, insect bites* With lemon juice; *Rheumatism* Embrocation with lemon juice; *Headache, lice, baldness* Paste with black pepper; *General antiseptic* Rub in

Leaves: *Itch, ulcers, scabies, herpes* Poultice; *Eczema* Ash, with sesame oil; *Ringworm* Juice; *Spleen enlargement, bleeding piles* Juice (internally)

Flowers: *Diabetes* Powdered, in curds

Bark: *Erysipelas, rat bite* Poultice; *Emetic* Juice, or charred bark

Roots: *Sinus* Juice; *Gonorrhoea, swollen testicles* Paste with coconut milk or rice water

Root bark: *Sinus* Ground with sesame oil and copper sulphate; *Rheumatism* Poultice

D3. KUSUM

Oil: *Itch, pimples, eczema, acne, scalp* Massage; *Laxative* Internally

Bark: *Acne* Ground with oil; *Back pain* Poultice

D4. NAHOR

Oil: *Sores, itch, rheumatic joints* Massage

Leaves: *Snake bite* Juice

Flowers: *Skin diseases* Powder with kusa grass (*Desmotachya bipinnata*), leaves of lodhra (*Symplochus racemosa*) and leaves of sirisha (*Albizzia lebbeck*); *Fainting fits* Paste with roots of *kusa* grass and shelled ber seeds (*Ziziphus mauritiana*); *Bleeding piles* Paste with butter; *Sprue* Mixture with rala (resin of *Shorea robusta*) and ghee (internally); *Gonorrhoea* With cardamoms and bamboo dew

Bark, Roots: *Convalescence* Infusion

D5. UNDI

Oil: *Itch, scabies, rheumatism* Massage

Resin: *Ulcers* Externally; *Purgative* Internally; *Sore eyes* Water extract

Bark: *Haemmorhages, purgative* Infusion

Inner bark: *Inflamed testicles* Warm poultice

D6. RAYANA

Oil: *Rheumatic pains* Externally

Bark: *Bleeding* Astringent, styptic

Group E. Trees with oilseeds that carry vegetable hard fats

E1. MAHUA

Seeds: *Tonsilitis, bleeding gums* Decoction as gargle

Oil: *Itch, headache* Emollient; *Constipation, haemorrhoids* Laxative
Leaves: *Sprains, rheumatic pains* Embrocation
Flowers: *Debility, impotence* In honey; *Sprue* Cold extract
Bark: *Itch, rheumatism* Paste; *Tonic, astringent* Decoction

E2. SAL
Resin, called rala: *Fumigation* Burnt; *Abscess* Mixture with ash of pipal tree bark (*Ficus religiosa*) in sesame oil, apply to ripen; *Skin problems* As plaster; *Lumbago* With egg white; *Ear discharge* In oil; *Dysentery* In ghee; *Piles* Paste with red sandalwood and ghee (externally); *Gonorrhoea, sexual debility, aphrodisiac* Boiled in milk or fried in ghee
Bark: *Ear discharge* Powder (blown in)

E3. DHUPA
Bark: *Malarial fever* (internally)

E4. KOKUM
Oil: *Fissures in feet, burning of feet, scrofula* As emollient, sometimes with castor oil; *Dysentery* Along with milk (internally)
Leaves: *Dysentery* Juice
Fruit: *Urticaria* Infusion with cumin seed and milk (internally); *Antiscorbutic* Infusion; *Bleeding piles* Powder cooked with cream (internal)

E5. TAMAL
Gum: *Boils, pimples, sprains, contusions* Massage (external); *Anthelmintic, dropsy* Internal, with care since a drastic purgative

E6. PHULWARA
Oil: *Rheumatism, chapping* Perfumed liniment and emollient; *Hair* Dressing

Group F. Trees with oilseeds bearing soap-making oils

F1. KHAKAN-PILU
Berries: *Constipation* As mild laxative, diuretic; *Snakebite* Internally; *Abdominal tumours* Ground with salt
Oil: *Rheumatism, itch, swelling* Emollient; *Piles* Suppository; *After childbirth* Strengthening (internally)
Leaves: *Scurvy* Internally; *Rheumatism* Poultice; *Poison* Antidote
Twigs: *Gingivitis* Chew
Bark: *Amenorrhoea, low fever* Extract
Root bark: Powerful *vesicant* (raises blisters), use with care

F2. PISA
Oil: *Sprains* External embrocation
Leaves: *Diabetes, urinary disorders* Infusion

F3. CHIRANDI
Oil: *Rheumatism* Embrocation
Bark: *Bruises, bleeding, insect bites* Juice; *Diarrhoea, dysentery, aphrodisiac* Concentrated extract

Group G. Trees that carry oilseeds with oils of unusual nature

G1. MAROTI
Seeds: *Wounds, ulcers* Paste; *Ophthalmia* Extract
Oil: *Leprosy* 10 to 20 drops after meals, massage also; *Scrofula* Internally, with ghee

G2. KAMALA
Fruit pubscence (dye): *Skin infections* Externally; *Tapeworms, purgative* Internally, with honey, jaggery or milk

G3. PINARI
Leaves: *Fever* Internally; *Insects* Repellent

G4. MALKANGUNI
Seeds: *Rheumatism, paralysis* Poultice; *Aphrodisiac* Internally; *Beriberi, dropsy* Oil obtained by destructive distillation of seed, called Oleum Nigrum (see Section 3.7 and Section 6.2), (page 107 and page 193)
Oil: *Sinus* In nose; *Fistula* Externally, for diuresis, with buttermilk
Leaves: *Brain inflammation* Poultice

*References as in Table 5

Table 7. Uses of oilseed plants in traditional Indian medicine: Groups H, I, J and K[a]

Group H. Shrubs bearing oilseeds

H1. RATANJYOTI

Oil: *Itch, scabies, sores, boils, leucoderma* Massage; *Rheumatism* Massage along with castor oil; *Purgative* Use with great caution

H2. GOKHRU

Oil: *Skin infections* Externally

Fruit: *Lip and mouth sores* Apply burnt fruit; *Urinary diseases, leucorrhoea, menorraghia* Boiled, mashed; *Smallpox* Cooling; *Chronic malaria* Infusion

H3. HURHUR

Seeds: *Diarrhoea, roundworms, spleen enlargement* Infusion; *Lack of appetite* Infusion as carminative; *Pneumonia* Along with juice of putikaranja (*Caesalpinia cristata*)

Leaves: *Ulcers, wounds* Poultice; *Earaches, deafness* Juice

H4. SOMRAJI

Seeds: *Leucoderma, skin diseases, abcesses, snakebites* Externally and internally; *Coughs* Internally; *Skin conditions* Both externally and internally; *Phlegm, Worms* Internally with caution

H5. ARGEMONE

Oil: *Ulcers, boils, scabies, itch* Externally; *Colic, purgative* Internally

Leaf: *Skin infections* Externally; *Dropsy, jaundice, gonorrhoea, diuresis* Juice (internally); *Conjunctivitis* Juice drops

Roots: *Tapeworm* Boiled

Group I. Trees bearing oilseeds

I1. AKRA

Leaves: *Snakebite* Pills of leaves macerated with milky akra sap; *Earache* Juice, with ghee, *or* Place paste with rice water in hollow stem of thohar (*Euchorbia neriifolia*), squeeze out juice, apply; *Dropsy, liver disease* Ash of leaves and rocksalt in closed vessel, give with buttermilk or vinegar; *Asthma* milky juice of tender leaves with pearl barley flour; *Ascites* Leaf ash

Flowers: *Catarrh, asthma* Purple flowers; *Cough* Purple flowers, infusion; *Cholera* White flowers

Milky sap: *Eczema* Apply with turmeric and sesame oil; *Rheumatic swelling* Paint as such, or sap mixed with plaster of dill seeds, *Cedrus deodhar*, asafoetida and rock salt; *Ear discharge* In hot ghee; *Toothache* In cotton; *Asthma* As such; *Dropsy, worms* As purgative

Root: *Jaundice* Macerate with rice water. put in nostrils: *Hydrocele* Apply paste with rice water

Root bark: *Jaundice* Pills with cumin seed, potassium carbonate, and tubercles of opium and nagarmusta (*Cyperus rotundus*); *Inflated testes* Paste in rice water

I2. SIMUL

Leaves: *Swellings* Poultice of oil-coated leaves

Flowers: *Haemmorhoids* Externally

Bark: *Open wounds* Paste; *Emetic* Infusion

Gum: *Dysentery, diarrhoea, impotence* Infusion (internally); *Styptic* Externally

Root: *Dysentery, diarrhoea* Infusion

I3. KAPOK

Leaves: *Gonorrhoea* Infusion

Gum: *Styptic* Externally; *Bowel complaints* Infusion (internally)

Roots: *Ascites, dysentery; diarrhoea* Infusion; *Diuretic* Hot infusion

I4. BAHEDA

Fruit: *Cough, hoarseness* Gargle with decoction; *Eye diseases* Decoction; *Dropsy, piles* Decoction as laxative; component of TRIPHALA with *numerous applications*

Kernel: *Dyspepsia* Suspension

Gum: *Purgative*

15. PALAS

Seed: *Abscess, ringworm* Poultice with lemon juice; *Intestinal worms*, Paste, juice or powder, with *Nux vomica* seed and guggal (*Commophora mukul*) gum added for Guinea worm; *Liver disease* Pills of powdered seeds with juice of *Euphorbia tirucalli* leaves; *Urine retention* Decoction

Leaves: *Eczema* Ash in sesame oil; *Sore throat* Decoction as gargle

Flowers: *Corneal opacity, eye disease* Juice with powdered karanja seeds; *Guinea worm* Juice with jaggery; *Gonorrhoea* Infusion with saltpetre and sugar; *Urine retention* Decoction

Wood: *Abdominal tumours* Take wood ash in water, marinate with long pepper, fry in ghee, administer with honey

Bark: *Open wounds, abscesses* Paste or decoction; *Mouth ulcers* Decoction gargle

Gum: *Diarrhoea* Mixed with sugar

16. TEAK

Oil: *Skin itch* Massage

Wood: *Swellings, bilious headaches* Paste, external; *Dyspepsia, vermifuge* Decoction (internal); *Swollen eyelids* Charred wood in poppy capsule juice

Bark: *Bleeding* Astringent

17. TAMARIND

Leaves: *Ulcers* Juice; *Dysentery, biliousness* Juice (internally)

Flowers: *Biliousness* With honey

Fruit: *Sunstroke, apoplexy, biliousness, diarrhoea, dysentry* Decoction as digestive, laxative

Shells: *Chronic dysentery* Ash of shells

Root: *Dysentery* Young root

Group J. Plants bearing fruit with oleaginous seeds

J1. MANGO KERNEL

Seed: *Burns, nose bleeding* Extract; *Roundworms, bleeding piles* Raw mash; *Diarrhoea* Roasted

Leaves: *Throat applications* Burning leaves

Midribs: *Warts on evelids* Ash

Flowers: *Diarrhoea, chronic dysentery* Ground

Fruit: *Feet fissures* Unripe fruit pulp; *Heat stroke* External and internal; *Scurvy* Fresh or preserved

Bark: *Internal haemmorhages* Infusion; *Diarrhoea, dysentery* Decoction

J2. THUMBA

Seeds: *Emetic, threadworms* Paste with buttermilk; *Jaundice*, Paste, to induce sneezing

Oil: *Headache* Massage

Fruit: *Ascites, urinary problems, gout* Dried, as drastic purgative

Roots: *Breast inflammation* Ground with water (internal); *Scrofula* Decoction; *During labour* Paste applied on vagina; *Emetic* Powerful

J3. WATERMELON

Seeds: *Weakness* Suspension cooling, diuretic, strengthening

Fruit: *Typhoid* Juice antiseptic, diuretic

J4. MUSK MELON

Seeds: *Urine suppression, eczema* Cooling, diuretic

Fruit: *Eczema* Fruit pulp

J5. LIME

Juice: *Bilious vomiting. heat palpitations* Internally; *Dementia* Apply on head; *Mosquito bites* Externally

J6. SWEET ORANGE

Flowers: *Sedative, antispasmodic* Steam distillate

Fruit: *Bilious diarrhoea, catarrh* Juice

Rind: *Acne, psoriasis* Poultice; *Dyspepsia, flatulence, general debility* Infusion (internally); *Vomiting, intestinal worms* Shreds: *Muscular pains* Rind oil massage; *Gout, dyspepsia* Internally with magnesia and rhubarb; *Foetid ulcers* Roasted pulp (external)

J7. PAPAYA

Seeds: *Abortion* Give unripe seeds

Milky juice of unripe fruit: *Anthelmintic* Powerful; *Tapeworms, bleeding piles, ulcers* Juice internally; *Abortion* Apply to uterus; *Ringworm, psoriasis* Apply externally; *Diphtheria* Apply externally, paint throat carefully

(*contd.*)

J8. SAPOTA

Bark: *Malaria* Substitute for cinchona

J9. SITAPHAL

Seeds: *Lice* Paste; *Abortion* Apply paste externally

Leaves: *Guinea worm* Paste (internal); *Ulcers, maggot-infested sores* Paste with tobacco leaves and quicklime; *Prolapse of anus in children* Infusion

Unripe fruit: *Vermin powder* Use with chickpea flour

Fruit: *Digestive* In convalescence

Bark: *Fever* Internally

Root: *Acute dysentery, Spinal disease* Acute purgative

J10. GRAPE

Raisins: *Cough, hoarseness, expectorant suppurative* Internally

Grapes: *Throat afflictions* Juice of raw fruit; *Dysentery, diarrhoea, dropsy, dyspepsia* Juice of ripe fruit; *Catarrh, febrile complaints* As demulcent, laxative, expectorant

Sap of branches: *Skin diseases, opthalmia*

Wood: *Bladder stone* Ash (in honey)

Vinegar from grape juice: *Indigestion, colic, cholera, emetic* Administer with salts

Group K. Plants bearing vegetables with oleaginous seeds

K1. AMBADI

Seeds: *Pains, bruises* Poultice; *Aphrodisiac* Internally

Leaves: *Aperient*

Flowers: *Biliousness* Juice with sugar and black pepper

K2. OKRA

Seeds and Fruits: *Gonorrhoea, urinary irritation, dysentery* Mucilage of value

Young pods: *Spermatorrhoea, gonorrhoea urine retention, cough, catarrh* Soaked

Leaves: *Dropsy, gonorrhoea, aphrodisiac, urinary problems* Internally

Roots: *Demulcent* Ground with sugar

K3. TOMATO

Nil

K4. CHILLI

Red pepper: *Stomachic, stimulant, rubifacient* Externally; *Hoarseness* (of professional singers or orators) Pellet with sugar and tragacanth; *Sore throat* As gargle; *Gout, malaria* With cinchona; *Rheumatism, dyspepsia, flatulence* Internally; *Cholera* Ground with asafoetida

Other chillies: *Plasters* Externally; *Cholera* Internally; *General* Counteracts effects of a bad climate or in disposition

*References as in Table 5

As an example of a powder, Samsharkar churna will serve. This powder consists of seven parts of ginger, six parts of long pepper, five parts of black pepper, four parts of nahor flowers (*Mesua ferrea*), three parts of leaves of tejpat (*Cinnamomum tamala*), two parts of cinnamon, one part of cardamom, and 28 parts of sugar.

Draksha arishta will illustrate a liquid confection. Raisins, molasses, cinnamon, cardamom, tejpat leaves, nahor flowers, fruit of priyangu (*Aglaia elaeagnoidea*), long pepper and black pepper are mixed and set aside to ferment. The strong aromatic wine is used as an expectorant in cough and hoarseness.

The soft sweet Gokshuradi avleh is made by boiling down to 40 ml a starting quantity of 160 ml water containing 1200 g of the extract of chottegokhru (*Tribulus terrestis*). To this is added 600 g of sugar followed by 30 g

each of long pepper, black pepper, cinnamon, cardamom, nahor flowers, tejpat leaves, the bark of the arjuna tree (*Terminalia arjuna*) and cucumber seeds, and 60 g of bamboo manna or dew, called tabashiri.

A pak is a thick confection, and Narikelakhand is one of them. To make it, 180 g of well-mashed coconut gratings are lightly fried in 60 ml of ghee, and 230 g of sugar and 250 ml of coconut water added before cooking to thicken. Finally 3.5g each of coriander seeds, long pepper, the tubercles of nagarmotha, bamboo manna, cumin seeds, carraway seeds, cinnamon, cardamom, tejpat leaves and nahor flowers are stirredin .

6.2 Modern Pharmacological Investigations

Some Successes

The Indian Materia Medica was published by Nadkarni in 1908[67A]. This catalogued the drugs from natural sources in use in India, many being those of the 500 or so listed by Charaka.[78b] In 1949 Vakil reported his striking success in the use of sarpagandha (*Rauwolfia serpentina*) for combating hypertension, followed by isolation of the active principle reserpine and elucidation of its structure. Another item, forskolin, isolated from *Coleus forskohlii*, formed the basis for the synthesis by Hoechst Pharmaceuticals of a derivative marketed for the same purpose. Coconut water, gokhru (*Xanthium strumarium*) and punarvana (*Boerhavia diffusa*) showed marked diuretic properties, along with a valuable high potassium level. For rheumatoid arthritis, the castor plant is one among several that has been found clinically effective. Another is gum guggal (from *Commiphora mukul*), which had even earlier been shown to have striking hypolipidemic effects, probably through the presence of three steroid constituents. The concept of promotion of wound healing, called *vrana-ropana* by Susruta, has been vindicated by results obtained with an ointment from the sunflower, a ghee medicated with the fragrant flowers of *Jasminum auriculatum*, and a decoction from the leaves of the sahadevi (*Vernonia cinerea*). Viral hepatitis and diabetes have shown clinical responses to certain plant products under controlled conditions. In Parkinson's disease, the atmagupta (*Mucuna prurita*) was found to contain L-Dopa and to reduce disabilities, but other unknown active ingredients were also present.[78b]

Systematic Screening Studies

The Cancer Research Institute, Bombay, has screened some 600 plants, and found that eight plants showed meaningful anticancer properties. Since 1964, the Central Drug Research Institute, Lucknow has systematically screened over 2000 species of plants for various types of action. Elsewhere in India, certain centres are testing out any materials that seem promising. Table 8 summarises this information in regard to the oleaginous species being considered in this book.[82,83,84]

While no dramatic results have been obtained, the activity shown by these and other plants appear to offer promise of a more holistic approach

Table 8. Pharmacological activities exhibited by oilseed plants[82,83,84]

Anticancer	
Calotropis gigantea	Root
Calotropis procera	Root, leaf
CNS-depressant	
Diploknema butyracea	Seed
Jatropha curcas	Plant, excluding root
Celastrus paniculatus	Seed oil
Limonia acidissima	Root
Hypertensive and cardiotonic	
Madhuca indica	Bark
Calotropis gigantea	Root, leaf
Antifertility (male)	
a) Spermicide	
Diploknema butyracea	Seed
b) Semen coagulant	
Madhuca indica	Bark
Bombax ceiba	Bark
Antifertility (female)	
Butea monosperma	Seed
Annona squamosa	Seed
Abortifacient	
Butea monosperma	Flower
Carica papaya	Unripe fruit
Hypoglycaemia	
Ricinus communis	Root
Melia indica	Seed
Terminalia belerica	Seed
Anthelmintic	
Melia indica	Leaf
Butea monosperma	Seed
Carica papaya	Unripe fruit
Analgesic and anti-inflammatory	
Calophyllum inophyllum	Seed
Mesua ferrea	Seed
Anti-ulcer	
Azadirachta indica	Seed
Tectona grandis	Bark
Hepatic	
Ricinus communis	Leaf

to health. As Charaka himself said: "Better a mild medication with no risk than a very strong medication with possible side effects.[78a]

6.3 Chemical and Medical Investigations on Some Indian Oilseed Plants

A2. COTTONSEED

Aqueous extracts of the whole plant, and especially of its leaves, exhibited uterine stimulant action in many species.[85] The leaf extract stimulated intestinal smooth muscle, showed diuretic activity and had hypertensive action.[86a] In lactating rats, greater milk yield through galactagogue action was reflected in increased litter weights.[86a]

A3. RAPE-MUSTARD

In rape-mustard seeds, release of pungent alkyl isothiocyanates was long known to be due to their liberation, through enzyme agency in the presence of heat and moisture, from glucosinolate precursors. Today several of the latter are known to be present in various species of *Brassica* (p. 51), yielding in turn several isothiocyanates, of which allyl and 3-butenyl are the chief entities. The distinctive types of pungency historically credited to various seed species and cultivars in India thus finds support from modern chemical evidence.

A4. COCONUT

Coconut water gave excellent results when used in congestive heat failure with peripheral oedema,[87] and also in gastric enteritis.[88] A significant increase in urine output followed intravenous infusion.[86b] The water carried an immunogenic factor which when injected into mice afforded moderate but statistical resistance to experimental tuberculosis.[89]

A5. LINSEED

Two unusual constituents present in linseed pass into the cake. One is the cyanogenic glucoside linamarin, which is hydrolysed by a thioglucosidase present to yield as much as 300 to 400 ppm of hydrocyanic acid.[90] The other is linatine: this is a pyridoxine antagonist which precipitates an acute pyridoxine deficiency when poultry are fed with the cake. The mucilage present in linseed to the extent of 7.45 per cent, which passes into the cake, has a high water-absorbing capacity in the animal stomach and improves the feed-utilisation efficiency.[91,92] Trypsin-inhibitor activity has been noted in the meal, but not either amylase or hemagglutinating activity.[91]

A6. CASTOR

The unusual constituents of castor seed, apart from of course its distinctive oil (which is dominated by a single hydroxy fatty acid, ricinoleic) are chlorogenic acid,[93] an alkaloid and two proteins.[94] The alkaloid ricinine is present in only small quantities, is only mildly toxic, and appears to be easily destroyed during processing.[95] The toxic protein ricin constitutes about 1.5 per cent of the kernel and 8 mg/kg in the meal, while the potent allergen, designated CB-1A, makes up as much as 6 to 9 per cent of the seed and 12 to 14 per cent of the meal.[96] Till recently the deleterious effects of the two could not easily be differentiated. Ricin has a molecular weight of about 60,000 and is highly toxic.[97] The quantity present in six seeds, about 0.18 g, is sufficient to kill a man when ingested, and by injection as little as 0.1 mg is lethal. Ricin is not hemagglutinating, nor is it proteolytic. Recent Japanese work has shown that ricin specifically cleaves ribose nucleic acids to which an adenine moiety is attached (these are present in the ribosomes of all animal species) leaving the remaining protein intact. Symptoms similar to food poisoning are the consequence.[97A] In contrast the castor allergen, with a molecular weight of about 100,000, is not toxic *per se* but has powerful agglutinating and proteolytic activity.[96] As with all allergens, immunity through production of antigens can be built up in man or animal by giving gradually increasing doses. This could have happened by natural exposure in India. The plant and seed grow wild everywhere, and reports of allergic manifestation, say among workers employed in castor seed mills, are rarely met with. Fevers and rashes soon pass away if they occur. The many applications of castor seed macerates as home remedies (Table 5, p. 176) further support the general prevalence of such immunity.

A8. SAFFLOWER

The deep yellow flowers of *Carthamus tinctorius* yielded a chalcone glycoside of deep yellow colour, which was named carthamine, whereas the ivory-coloured flowers contained a colourless flavone glycoside that was called neocarthamine.[98,99] No pharmacological studies have been reported.

B3. SUNFLOWER

The extract of the whole plant with 50 per cent ethanol was found devoid of any pharmacological activity, whether against protozoa, helminths, viruses or cancer; neither was the extract hypoglycemic, diuretic, antispasmodic, analgesic nor hyperthermic.[100] Earlier the leaf extract had shown activity against *Staphylococcus aureus*, though not against *Escherichia coli*.[101a] In rats, the whole plant alcoholic extract definitely hastened wound healing, as shown by earlier formation of collagen fibre and rapid appearance of mucopolysaccharides.[102] The capacity of sunflower seeds to elaborate aflatoxin was considerably lower than that of groundnuts.[103]

C5. RUBBER

The seeds of *Hevea brasiliensis* contain a cyanogenic glucoside, linamarin. This is also present in linseed, but the quantity here is slightly less, from 70 to 220 ppm.[104a] The glucoside is hydrolysed by an enzyme present to glucose and acetone-cyanhydrin, which in turn yields acetone and hydrocyanic acid. Keeping or drying rubberseed, and normal seed processing, bring down the hydrocyanic acid content to very low levels. A foetid diarrhoea in rats, attributed to necrotic enteritis, has been noted (page 321). Ingested linamarin itself is efficiently metabolised by rats.[105]

C7. JUTE

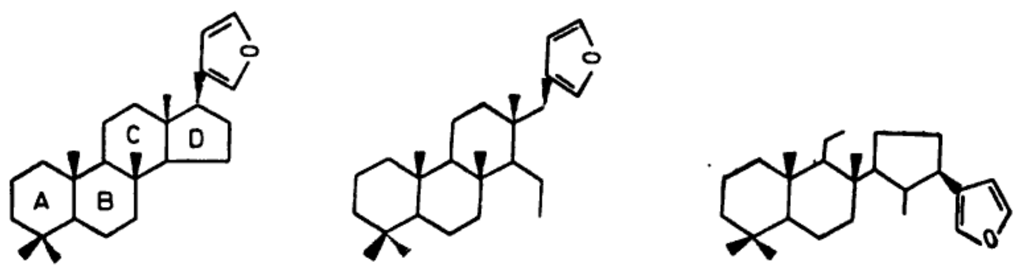
Four glycosides have been isolated from the seeds of *Corchorus capsularis*.[105,106] These are Corchoside A, helveticoside, olitoriside and erysimoside, but no pharmacological studies on these have been made. The fruits of the jute are rich in vitamin C.[86c]

D1. NEEM

Nature of lipid associates: Odorescent and bitter constituents are present in the seed, and indeed in the leaves, stem and bark as well.[104b] The odorous compounds present in neem oil carry sulphur. This probably occurs in a thioketone linkage because: (a) carbonyl-reacting agents yield hydrogen sulphide; (b) Clemmensen reduction with zinc and hydrochloric acid gives an odourless compound; (c) saponification with alkali yields sulphur; and (d) refluxing the oil with alcoholic hydroxylamine, followed by vacuum steaming, yields a deodorised oil. However, the nature of the sulphur compound or compounds has not been elucidated.

The bitter compounds have been extensively characterised. They can be considered as mainly of three types, with the basic skeletons shown in

Fig. 17.[107] Type A, in which all four fused rings are intact, is a typical tetranortriterpene and many compounds isolated from the neem plant belong to this group. The compounds include azadirone, azadiradione, vilasinin, and nimbidimin. Type B is of far less common occurrence, and is exemplified by gedunin and its 7-desacetyl, and 7-benzoyl, derivatives. The third type has again a fair number of derivatives, among which are azadirachitin, salannin, salannol, nimbin and nimbolinin. The first structure, that of nimbin (Type B) was established in 1964, and the structure and anti-feedant properties of meliantriol and azadirachtin were reported soon after. The presence in the same plant of such a diversity of triterpene products representing so many levels of oxidation is indeed a unique example of the functioning of nature. Two recent reviews list tetranortriterpenoids isolated and characterised from woods of plants of the Meliacea family.[107,108]



Type A Type B Type C

Fig. 17. Structural types of the bitter components of neem

Pharmacological studies: The odorescent components of neem seed have been related to some of its properties, but no systematic studies have been reported. The bitters of neem twigs and leaves have been reported responsible for its effectiveness in dental hygiene.[104b] Both gingivitis and periodontis showed clinical response to an alcohol extract of neem bitters, based on which a German Patent was registered.[109] Several neem-based toothpastes are on the Indian market. Nimbidin, part of the bitters isolated from neem seed, was reported to show antistress and adaptogenic properties in relation to ulcer formation.[110]

The leaves of neem are being widely studied. Extracts prevented the multiplication of vaccinia and of fowlpox in cell cultures, acting at the adsorption stage of the viral growth cycle.[111a] A concentrated infusion provided "definite improvement and cure in all cases of acute eczema, ringworm infection and scabies", even where previous treatment with standard preparations had failed.[112] The treatment was required only for a short duration. "In some cases, only two days' application was sufficient."[112] Concentrated aqueous extracts of neem leaves, given as capsules

on an empty stomach in human ascariasis, were highly effective even where potent anthelmintics had failed, the patient being freed of both worms and ova.[113] In dogs with adrenalin-induced and glucose-induced hyperglycemia, neem leaf extracts showed both hypoglycemic as well as anti-hyperglycemic effects.[114] Neem oil taken orally was synergistic to anti-diabetic drugs, including insulin.[114A]

Charaka described, 20 to 25 centuries ago, the fumigation of women to prevent conception.[115] Live coals were placed in a special kettle with a thin spout, the end of which was covered with some soft material. Powdered neem wood was sprinkled over the coals, and the end of the spout was gently inserted into the vagina as the woman sat with legs astride. The method is apparently still in use in India. Neem leaf extracts have been shown to affect male fertility. Oral administration of 1 ml/100 g bodyweight daily to mice, rats, rabbits and guineapigs totally reduced fertility after 11 weeks of administration, mainly through marked reduction in the motility of spermatozoa.[111b] The effect was reversible in four to six weeks. In another study, neem leaf extracts markedly reduced the heartbeat rate of anaesthetised guineapigs and rabbits,[116] which may account for the high death-rate noted.[111b]

The use of neem oil in fertility has been examined. Neither neem oil itself, or its bitter fractions, showed oestrogenic activity.[111c] Single or multiple intravaginal application of neem oil in rats during the preperi and post-implantation periods prevented pregnancy: after withdrawal of treatment, fertility was restored in 30 days, and the pups were born normal.[111d] These effects were also shown in monkeys and humans *in vivo*. In other studies neem oil in rats and rabbits exhibited a mild anti-ovulatory effect and subsequent anti-implantation activity on the tenth day of pregnancy.[111e] In males, significant anti-fertility effects were noted without interference with spermatogenesis. *In vitro*, neem oil showed strong spermicidal action against both rhesus monkeys and human spermatozoa.[117] An intervaginal dose of 0.20 ml in rats,[117A] and 1 ml in rhesus monkeys and human subjects, prevented pregnancy.[117] However, caution is indicated by the finding that children aged six months to three years, given a dose of 25 to 60 ml of crude neem oil in the home for respiratory problems, and brought to hospital with convulsions, showed acute toxic hepatic and brain injury.[118]

D2. KARANJA

Lipid associates: Karanja seed oil on standing deposits some 1.25 per cent of a crystalline compound named karanjin, later identified as a furanoflavone.[119] Another constituent of the oil, pongamol, turned out to be a furanodiketone.[120] Most of the dozen other constituents present are structurally related to these two compounds. A third compound present, glabrin, is unusual in being a nitrogen-containing pipecolic acid derivative.[121]

The presence of these constituents explains many of the properties of the oil.[104c] Self-precipitation of karanjin, pongamol and several other constituents in an amount of 3 to 4 per cent of the oil was an early source of these products. Since these furano compounds are also volatile, karanja oil is beneficiated (p. 297, p. 300-303 and p. 304) by steam distillation, followed by splitting and distillation of fatty acids of high quality. Soap made from karanja oil changes in colour from orange to green and then to brown because of the susceptibility of the sodium salts of the chalkones present to rearrangement, and the enolic character of pongamol. The marked improvement noted in karanja oil by acid treatment (page 304) is because sulphonated and sulphated flavanoids are removed as gums, as well as nitrogen-containing glabrin.

Pharmacological effects: The insecticidal and anti-feedant effects of karanja cake and oil have been described elsewhere (page 326).

Karanja oil showed activity against several pathogenic bacteria, like *Salmonella paratyphi A*, *Micococcus pyogenes* var. *aureus* and *Salmonella typhosa*, being more active than even neem oil against the first of these.[122] At 10 ppm, but not at 1 ppm, isolated karanjin showed high antibacterial activity against a strain of *M. tuberculosis*.[123,124] Karanja oil was much more effective against mange in goats than a sulphur ointment or benzyl benzoate.[101b]

Expeller cake is toxic to poultry, but not karanja solvent meal, which again implicates the lipid associates of the oil.[111f] In fact the meal has been fed to poultry for 170 days with no effects other than a slight gain in spleen weight of cockerels.[111g]

The oil is toxic to many animals, and this includes its acidic, neutral and basic fractions.[111h] It has long been used for skin diseases like itch, scabies, leucoderma and psoriasis, the curative effects undoubtedly arising from the lipid associates present.

The seeds are reported to contain a hypotensive principle, as well as a compound causing uterine contraction,[104d] but neither has been fully investigated or related to chemical entities.

D3. KUSUM

Belief in the beneficial effects of kusum oil, the original macassar oil, on hair growth is of long standing. It is therefore interesting to find that the oil is indeed of an unusual nature, with just 37 per cent of common glycerol esters. The rest consists of two cyanolipids, each esterified to two fatty acids, of which 58 per cent are esters of cyanolipid I, and 5 per cent of cyanolipid II.[104e] However the effectiveness of these as hair growth stimulators awaits experimental proof.

D4. NAHOR

The presence of resins imparts to nahor seed oil a reddish colour and a greater viscosity than normal. From the oil have been isolated three coumarins, phenolic in nature, called mesuol, mesuagin and mammeigin,

though all three need not be present in every sample of nahor oil.[125,126,127] These flavones are the reason for the deepening of colour on alkali addition (p. 307), and the use of the oil in skin ailments and rheumatism may well be connected with their presence.

D5. UNDI

The oil of *Calophyllum inophyllum*, with a dark green colour, disagreeable taste, unpleasant odour and high viscosity, carries from 10 to 30 per cent of resins which have been shown to contain a series of related 4-phenylcoumarins which resemble each other.[104f]

Calophyllide is reported to be an anticoagulant, and also to be physiologically active against leprosy and tuberculosis bacilli.[104f] Analgesic and anti-inflammatory activity has been reported from two laboratories for the coumarins themselves and their xanthone derivatives,[128] and again for calophyllide, one of the isolated coumarins.[129]

E1. MAHUA

The unusual components of mahua reside not in the oil, but in the cake. These consist of of two saponins, collectively called mowrin, in both of which the aglycone is protobassic acid though the sugars differ. Protobassic acid on release rapidly dehydrates to give bassic acid, which was therefore erroneously taken to be the aglycone.[104g,130] Mowrin forms about 7 per cent of mahua seed meal.

The physiological effects of mowrin and mahua cake on animals have been described elsewhere (Section 11.3, page 328). Total mahua saponins at 2 per cent concentration showed spermicidal action on human semen, but neither cardiovascular nor haemolytic effects.[101c]

E2. SAL

The tannins present in sal seed meal to the extent of 8 to 2 per cent probably consist of oligomers of flavan-3-ols. Some free tannins also appear to be present, since ellagic acid has been isolated in very small quantity (0.1 per cent).[131] Ellagic acid controls haemorrhage in animals and humans,[132] and appears to act by activating the natural blood-coagulation system.[133] Another recent finding is that ellagic acid nullifies *in vitro* the carcinogenic potential of substances like benzo(a)pyrene in a strain of *Salmonella typhimurium*.[104h] Whether any of these effects arise in feeding sal cake, which carries the tannins, is of course still open to proof.

E3. DHUPA

The resinous material present in dhupa cake has not been characterised. It appears to be of a phenolic nature in that a violet compound is produced on exposure to iron, and weedicidal effects have been noted.[134] A glycoside bergenin has also been postulated which is unpalatable to cattle.[135a]

E4. KOKUM

From the fruit rinds of *Garcinia indica*, two isomeric polyphenols named garcinol and isogarcinol have been characterised,[136] but no pharmacological work has been reported.

E5. TAMAL

The other *Garcinia* species, *G. morella*, has been the subject of study because of the striking antibacterial activity against *Micrococcus pyogenes* var. *aureus* exhibited by the seed pericarp, leaves, fruit and stem bark.[137] All these contain morellin, which is bright yellow in colour, and structurally an oxygen heterocyclic.[138]

Morellin in clinical trials showed promising results in wound healing,[86d] and in diseases of the mouth.[104i]

The cathartic activity of the gum resin and seed coat have been traced to the presence of two guttiferins.[139]

F1. KHAKAN-PILU

The seed oils of the two *Salvadora* species, when obtained by solvent extraction of seed, carry no smell of benzyl isothiocyanate; the ghani oil however has a pungent odour and yields 1.5 per cent of the compound on steam distillation, showing that it is a hydrolysis product of the parent seed glucosinolate, glucotrapaeolin. Benzyl isothiocyanate is a powerful bactericide and fungicide (p. 195). The unsaponifiable fraction, even of the solvent-extracted *Pilu* oil, contains symmetrical dibenzyl thiourea, symmetrical dibenzyl urea and a nitrogen-carrying compound with a thioketone structure.[104j] The seeds also carry both quercetin and rutin.[140] The relationship of these to the use of the seed in various abdominal complaints remains conjectural.

F3. CHIRANDI

The strong aromatic odour of the oil of *Litsea glutinosa* is through the presence of an essential oil in the seeds[135b] in which numerous components have been identified: ocimene, α-pinene, d-limonene, terpinolene, α-terpinene, carvone, carophyllene, β-amyrin acetate, fenchyl alcohol, α-thujone and linalool oxide.[101d] This essential oil had no antibacterial activity, but exhibited a prolonged hypertensive effect with marked stimulation of respiration in dogs.[141] The oil extracted from the whole berries, when administered to rats, caused a reduction in spontaneous motor activity without concomitant muscle weakness, and an analgesic effect.[142]

G1. MAROTI

The effectiveness of the *Hydnocarpus* oils maroti and chaulmoogra against the leprosy bacterium,[143] empirically established centuries ago in India, has been linked in modern times to the presence in these oils of three cyclopentene fatty acids (page 311). These oils were used both externally and internally, usually along with ghee to improve their palatability.

Medicated soaps were also employed. Later the ethyl esters were injected intramuscularly and intravenously. Though in modern medicine drugs like Rifamycin and Rapsone are employed, maroti and chaulmoogra oils continue to find use in India against leprosy.

The powerful antimicrobial activity of these fatty acids appears to be due either to the inhibition of biotin synthesis, or to inhibition of the coenzymic activity of biotin.[144,145] About 15 species of *Mycobacterium* have been shown to be susceptible to hydnocarpic acid, including some like *M. intracellulare* that are resistant to other agents.[143]

G2. KAMALA

The dye from the outer pubescence of the kamala capsule contains rottlerin, which is red, and isorottlerin which is yellow, besides kamalins I and II.[101e] In rats and guineapigs, rottlerin has the antifertility effect,[146] not shared by isorottlerin,[147] of disturbing the oestrus cycle and prolonging the dioestrus phase. The total pigment is also effective against tapeworms.[148]

The fruits of *Mallotus philippinensis* carry chromanoflavones and pyranochalcones.[149] Extracts had a significant purgative effect in rats,[150] perhaps caused by the external resin.[151] Seed extracts showed no antifertility effect,[152] but did exhibit antispasmodic activity on an isolated guineapig ileum,[153] and also antibacterial action.[154]

The oil carries an unusual conjugated triene fatty acid, and has an unconventional assembly of fatty acids (page 311), but its pharmacological activity, if any, has not been examined.

G3. PINARI

The oil of *Sterculia foetida* carries 59 per cent of cyclopropene fatty acids, which have several untoward effects when consumed. These include greater weight gain in the rat,[155] besides liver lipid accumulation and protein depletion,[156] aortic atherosclerosis in rabbits,[157,158] cocarcinogenic action to aflatoxin in rainbow trout,[159] and a pink discolouration of the egg yolk in laying hens.[160] A particularly striking effect is the inhibition of the desaturase enzymes that convert stearic to oleic acid in the animal body,[156,157] leading to a build-up of stearic acid. Even the small amount of cyclopropene fatty acids present at 1 to 2 per cent level in the fat remaining in cottonseed expeller cake is sufficient to cause a hardening effect on milk and body fats if the cake is employed as a feed.[161] Refined cottonseed oil which contains up to 2 per cent of these acids is specially deodorised under acidic conditions to destroy the cyclopropene moiety.[162]

The presence of 5 per cent of sterculic acid in a rat diet is sufficient to bring about death.[135]

G4. MALKANGUNI

The presence in the oil of *Celastrus paniculatus* of formic, acetic and benzoic acids was noted long ago, but only recently has the mode of occurrence of these in the oil been unravelled.[162,163,164,164A,165] Apart from

the usual glycerol esters, malkanguni oil contains about 7 per cent of the esters of two isomeric sesquiterpene alcohols. The chief one is malkanguniol, which is esterified at the 8 and 9 positions with acetic and benzoic acids. The isomeric celapanol is also esterified: with acetic, nicotinic, and benzoic acids to give celapanigin, and with acetic, nicotinic and furoic acids to give celapanin.

The traditional destructive distillation of malkanguni oil in India to yield a black distillate, oleum nigrum, used as a specific for beriberi (Section 3.7) finds scientific support in the presence of nicotinic acid as an ester in the oil. Oleum nigrum is a powerful brain-stimulant, its ingestion being followed in a few hours by free diaphoresis unattended by any feeling of exhaustion.[135d]

Both intramuscular and intraperitoneal administration of the oil caused sedation in rats, the former more strongly; in cats, the outcome was a fall in blood pressure.[86e] Malkanguni seeds contain two alkaloids, celastrine and paniculatine, which are stimulants.

H1. RATANJYOTI

The seeds of *Jatropha curcas*, the oil of which is violently purgative, carry three unusual principles. The first of these is a resin with a nauseating smell and purgative action, which does not appear to have been characterised.[135d] The other two are toxic proteins, curcin and curcasin. These are toxalbumins that resemble the ricin of castor seed but are less toxic.[166] Fish are highly susceptible to curcin, but mice survived even interperitoneal and subcutaneous injection of the proteins.[167]

The alcoholic extract of the whole plant caused diuresis in rats, and depressed central nervous system action.[168] Extracts of the fruit epicarp produced hypotension, cardiac depression and marked haemolysis of human erythrocytes.[169] Extracts of the seed shell reduced blood pressure in dogs, and stimulated plain muscle of the intestine, while an extract of the defatted pulp exhibited a marked haemostatic effect, pushing down strongly the bleeding and coagulation times.[101f]

H4. SOMRAJI

Subcutaneous injections of epoxystearic acid, which constitutes 78 per cent of *Vernonia anthelmintica* oil, produced sarcomas with fair frequency in rats[169A] and in mice.[169B] This contrasts with the high traditional reputation of the oil as an external cure for skin conditions, and internally for prolonging life and restoring youth (Section 3.8, Item H4).

H5. ARGEMONE

The oil of *Argemone mexicana* carries an alkaloid of isoquinoline structure, termed sanguinarine, to which is attributed the extreme toxicity of the oil.[170] It exhibits both acute and chronic toxicity in rats even at a dose one-thousandth the LD_{50}.[86f] Several outbreaks of the toxic syndrome, termed epidemic dropsy, have been traced since 1937 to contamination of

the edible oil used for cooking with argemone oil.[171,172,173] A link between sanguinarine and glaucoma has also been postulated.[174] A permissible limit as low as 0.01 per cent for contamination with argemone oil has been suggested for public health purposes on the basis of toxicity studies.[175] Numerous tests for the detection of sanguinarine at very low levels (500 ppb) have been devised.[176] A series of studies showed that while sanguinarine itself was not toxic and neither was solvent-extracted argemone seed oil, expeller oil was: a potentiating effect on sanguinarine by the oxygenated fatty acids present in argemone oil (see p. 313) was postulated.[177]

The roots and stem together carried 0.125 per cent of the alkaloids protopine and berberine in a 2:1 ratio, besides tannins and resin; these alkaloids produced a fall in blood pressure and stimulated smooth muscle in a manner reminiscent of pitocin.[178] The alcoholic plant extract showed activity against the virus of the dread Ranikhet disease of poultry.[154]

11. AKRA

Several compounds have been isolated from the leaves of the two *Calotropis* species: the glycoside calotropin,[86g] uscharin, calotoxin, and later asclepin;[179] and an active principle mudarine, a resin, and a bitter acid.[86g] In tissue culture studies, the root and leaf extract was found to be active against human epidermal carcinoma of the nasopharynx.[154,180]

The crude latex exhibited high fibrinolytic and anti-coagulant activity in human and rabbit plasma, and marked stimulant effect in a rat uterus.[86g]

Extracts of the root of *Calotropis* showed a strong vermicidal effect against earthworms; the extracts also induced the contraction of several muscles (duodenum, ileum and uterine horn) and showed a stimulant effect on isolated hearts of the frog and rabbit.[180]

12. SIMUL

The root bark of *Bombax ceiba* contains three naphthalene derivatives, all related to gossypol. The root, stem and bark carry glycosides and tannins, and the stem some alkaloids besides.[181] The flowers have been shown to contain quercetin and kaempferol.[182]

The hot aqueous extract of the seeds showed moderate oxytocic activity in the isolated rat uterus; musclotropic action in the guineapig ileum; and cardiac-stimulant action in the frog heart.[183]

15. PALAS

Several flavonoids are present in the flowers and seeds of *Butea monosperma* such as butin, butein, sulphurein and palasitrin.[184] These can each occur as more than one glycoside depending on the sugar moieties attached. Glycosides isolated from the petals reduced the number of implants in mated rats,[185] while palasonin, the glycoside in the seeds, showed anthelmintic activity *in vitro* against *Ascaris lumbricoides* and *in vivo* against *Toxicara canis*.[186] Alcohol and light petroleum extracts of

the seeds inhibited ovulation in rats.[187] Feeding of the green matter to rats, rabbits and dogs for two months produced marked anaemia and nephrotoxicity, with gross dilation and chronic inflammation of the stomach, and congestion in liver, lungs and spleen.[188]

J1. MANGO

Mango leaves are aromatic through the presence of 3-carene, ocimene, terpinene, camphene and sabinene,[189] and the flowers also carry most of these components and tannins besides.[190] Even the fruit and seed kernel contain gallotannins, while many of the tissues of the mango carry a distinctive xanthone-glucopyranoside that has been termed mangiferin.[191]

Mangiferin has been shown to be protective against liver injury by carbon tetrachloride.[101g] It has no analgesic activity, but causes stimulation of the central nervous system in rats, and a cardiostimulant action in the perfused dog heart.[192] The use of mango leaves as a dentifrice was vindicated when the extract showed antibacterial effect, suppressed coagulase activity, and depressed mannitol fermentability by staphylococci.[193]

J2. THUMBA

The glycopyranoside of eletrin, isolated from the bitter pulp of *Citrullus colocynthis*, has been termed Coloside-A. This was found to be purgative, and showed anti-histamine and anti-acetylcholine activity on an isolated guineapig ileum and rabbit intestine. Some depressant effect was observed on the heart of a frog, but not on that of a dog.[194]

J7. PAPAYA

Various seed fractions, and most especially the resin component, were found effective against tapeworms in rats *in vivo* and also *in vitro*.[86h] Benzyl thiourea was identified in the seed oil,[195] and was held responsible for the anthelmintic activity.[196]

From the dried seeds of papaya were isolated glucotrapaeolin,[197] the same glucosinolate found in khakan seeds. Its hydrolysed product, benzyl isothiocyanate, showed bactericidal and fungicidal activity when tested against 57 microorganisms, and could well be useful in certain intestinal and urinary infections.[197] Papaya seeds showed maximum antibiotic activity when fresh, and had a low toxicity.[197] A bitter saponin (1 per cent) and sapotinin (0.08 per cent) were also found present.[135e]

In other studies the seeds decreased rat fertility, but were found to be highly toxic.[86h] They also showed significant anticoagulant activity.[198,199]

The latex of the green fruit exhibited high oxytocic activity.[86h]

J8. SITAPHAL

The seeds of *Annona squamosa* showed slight uterotonic action in isolated tissue experiments, but little oxytocic activity.[86l] An alcohol extract of the aerial parts of the plant, in tissue culture, exhibited anticancer activity in human epidermal carcinoma of the nasopharynx.[180] The several

aporphine alkaloids isolated include corydine, for which anticancer activity has been reported.[200]

The resin in sitaphal seed oil, which settles down as an oily globule on standing, constitutes the potent insecticidal and piscicidal principle (see p. 329).

J11. KAPITTHA

From the leaves of *Limonia acidissima* were isolated, besides psoralen and bergopten, three flavone glycosides.[86j] The trunk yielded a keto-lactone which exerted a powerful spasmogenic effect on the isolated rabbit gut through a cholinergic mechanism.[201]

K1. AMBADI

Rats fed with 10 per cent of *Hibiscus sabdariffa* oil showed inferior growth and reproductive performance. Liver weights were high and liver lipids altered, but all organs were histopathologically normal.[202] In the Ames test, ambadi seed oil, both without and with activation, showed high mutagenecity potential in a rat liver homogenate preparation.[203] The epoxy and cyclopropene fatty acids present in the oil could perhaps be responsible (Section 10.3, p. 314).

K3. TOMATO

The seeds of *Lycopersicon lycopersicum*, the common tomato, carried two flavonoids, quercetin and kaempferol.[204] The acetone extract of the leaves, but not of the fruit, showed a potent local anaesthetic effect,[101h] while the leaf alcoholic extract was a depressant of the central nervous system.[205]

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PART

PROCESSING

CHAPTER 7

The Ghani

7.1 Origin of the ghani

ANTIQUITY OF CRUSHING DEVICES

Historical references : About 2000 BC, at least two oilseeds, the sesame and the linseed, were known to the Indus Valley civilisation.[1] The archaeological find of a copper frying pan from Mohenjodaro would also imply that frying using oils was practised, though animal body and milk fats could also have been so employed. While the later Aryans prized ghee exclusively for cooking, and would countenance no other fat, the use of vegetable oils among the natives must have prevailed all along. Even as late as 200 AD, the physician Charaka remarks that though accustomed to employing only vegetable oils, non-Aryan kings lived healthy and productive lives, so the practice must have some merit.[2]

The earliest Aryan compilation, the *Rigveda* (c. 1500 BC) graphically describes how the soma plant was crushed between stones called *grava* to yield an exhilarating drink,[3] the noise of the operation being compared to the bellowing of harnessed bulls.[4] In the later *Sathapatha Brahmana* of c. 800 BC, both the use of two grindstones, or of a stone pestle and mortar called *ulukhala*, for the crushing is specified.[5] From a small domestic ceremony, the ritual at which soma juice was prepared gradually enlarged by about 500 BC to include 16 priests,[6a] and doubtless the mortar (*ulukhala*) and its pestle (*musala*) also increased in size.

At Dwaraka, in Gujarat state, a number of abandoned stone mortars found at various locations in the state have been assembled and arranged in two facing rows in a park, with captions below each describing their use for crushing soma juice (Plate 16). However, these might equally well be old stone ghanis employed for crushing oilseeds: the design is exactly that of the ghani used for this purpose today, and there is even a drain hole from the pit in one of them.

Sanskrit terminology: From the earliest writings, the term used from the sesame seed was *tila*, and for sesame oil *taila*, while *tilaka* meant of or from *tila*. To denote an oilpress, these words were modified with three terms: *peshana* (to grind), *yantra* (machine) and *chakra* (wheel).[7a,7b] Thus

we have *tila-* or *taila-* or *tilaka-* placed before *-yantra* or *-chakra* or before *-peshana-yantra* or *-peshana-charka* or *-yantra-chakra* to denote in every instance an oilpress (*Bhavisya Purana*).[8a,8b] Later the word for sesame oil, *taila*, became the generic word applied to all vegetable oils, which the modern Hindi word *tel* still perpetuates. *Teli* then as now was the oil-miller.

GHANI, KOLHU AND CHEKKU

Usage: Ghani is the term most commonly applied in India today for the oil-crushing device; the first 'a' and the terminal 'i' can be long or short, and the 'n' sound soft or, less commonly, hard. Ganuga and guruga are variations found in the south. In the Indo-Gangetic plain, and in Bengal and Orissa, the term kolhu is in common use, especially for the rotary oilpress with a revolving mortar used to crush rape-mustard seeds. The presses employed to crush sugar cane juice are also called ghani and kolhu.[9a] Indeed even a century ago Watt remarks that both in the north-west of India, and around Lucknow, presses for crushing oilseeds and sugar cane are both identical, except for a smaller size for the former.[10a] In the Marathi language, *khali* or *khal* is used to mean both oilcake and sugar,[11] the products of the respective crushing. A pounding mortar shown in one of the sculptured panels of the Sanchi Stupa (c. 200 BC) has an hour-glass shape resembling that of certain ghanis.

Ghani: The word ghani is considered a colloquial or dialectical one. Commenting on its use in an inscription dated 1264 AD from Veraval in the Junagadh district of Gujarat (Plate 17), the editor remarks that proper Sanskrit usage would call for *taila-peshana-yāntra*.[13] Yet in the *Arthasastra*, written about 300 BC by Kautilya, the word used for oilcakes is *ghānapinyāka*,[12a] so the term *ghana* is fairly ancient even in writing. For later usage of the words ghana, ghani and the Sanskritised from *ghanaka*, one has mostly to turn to inscriptions rather than to literature. In a stone inscription from West Bengal (of the fifth or sixth century AD), the boundary of a certain field is stated to be a *sarshapa* (mustard) *yanaka*, and it is likely that the 'ya' is a misreading or engraver's error for the very similar letter 'gha'.[14] The two Siyadoni inscriptions found near Gwalior (Madhya Pradesh), dated 903 and 969 AD, carry the words *ghānaka* and *ghrānaka* with a hard 'n', each word moreover being used twice.[15] The term *ghana* for an oil mill appears in a 997 AD inscription from Bijapur,[16] *taila-ghanaka* in a 1055 AD inscription from Nashik,[17] and *ghanaka* in a 1207 AD inscription from Chitorgarh in Rajasthan.[18] A late Sanskrit classical work, *Ballālacharita* (1510 AD) uses *ghanaka* for an oilpress.[19] Ghana or ghani was clearly employed in common speech in many parts of North India by the tenth century AD.

How did it originate? Perhaps the word was an amalgam of many associations. In classical Hindi, the spoken and written successor to Sanskrit, the term ghani means to harden, thicken or solidify, while the word ghan connotes one load or charge of the oilpress.[9a] Did the term

ghana or ghani arise from these, as seems probable, or was it the reverse? One scholar has suggested that ghani is a composite of ghana, for an ordinary grinding mill, and the Vedic term *gravan* for grinding stone, but the deduction is noted alongside as being unsatisfactory.[21] There could be other complex associations. The Vedic stones used to crush soma juice were termed *gravan*,[20] and ghavan is used currently for a stone mortar in Marathi.[21] In Gujarathi ghatani is a mill, and ghatanika means pounding.[21] Both the *Ramayana*[22] and the *Matsya Purana* use ghatanika for mace or club. Behind the term ghani may lie such strands of usage.

Kolhu: Here again an essentially spoken word appears to have later been Sanskritised. An inscription dated 933 AD from the Vaillabhatasvamin temple in Gwalior (Plate 18) records a pledge of the oil-millers to supply oil to the temple, and though the language used is a very archaic form of Sanskrit, the word employed for oil mill is *kolhuka*.[24] In the forging of this word, some trends can be discerned. The Rigvedic term *ulukhala* for the mortar used to crush soma juice[6b] yielded the word *ulukhalika* for the act of grinding, and by 750 AD the word khali is being used both for oilcake and for sugar.[9a] A small mortar came to be called *ukhli* or *okhli*,[9c] derived from the terms *ikh* and *ukh* denoting the sugar cane, and themselves derived from the classical Sanskrit word *ikshu* for this commodity. In classical Hindi, oilcake is termed kalkaja or simply kalka,[9d] and even today the mortar of the ghani is called aukhali in Hindi. From such words, the term kolhu is not a far cry.

Chekku: As we have seen, one Sanskrit word for the oil mill was *tailika-yantra-chakra*, literally oil-mill-wheel, which could easily get abbreviated simply to *chakra* or wheel. In Pali, this gets softened to *chakka*, and is employed for any wheel or millstone.[9e] Today this word is widely used in the form chakki. In south India, the ghani is commonly referred to as chakku or chekku, and the latter term for oil mill occurs in Tamil literature of the seventh and the eighth centuries AD, the *Naladiyar*[25] and the *Nalayira Thivya Prabhandam*.[26] That the oilpress existed even earlier seems likely from the reference in the *Purananooru* of the second and the third centuries AD to the *nurai* or froth on the surface of oil (Plate 19) extracted from sesame seed,[27a] which is very typical of oil as it freshly appears in a ghani (p. 217 and p. 218).

Certain other words now in use for the oil mill in Tamil also have a Sanskrit origin, like yantiram or yentiram (from *yantra* or wheel) and thirikaiyattam (hand wheel).[28] Later and less common terms seem to be local, like salai and utrumaram (from a log).[28]

Ghani evolution: There are references in ancient literature to some type of pressure grinding of oilseeds to yield oil. Sesame seed was known to the Harappans, and sesame oil is mentioned in the *Atharvaveda* (c. 1000 BC).[33] Guilds of oil-millers find repeated mention in Buddhist literature from about 400 BC. Oil mills themselves are referred to in the *Mahabharata*[7a] and in the grammar of Panini (both of about 500 BC),[7a] and in Kautilya's *Arthasastra* of two centuries later.[12b] Few really old oil mills have

survived. Those assembled at Dwaraka, referred to earlier in this Chapter, have been dated to the first two centuries of the Christian era from associated evidence,[33A] and are thus the oldest ones known. Stone ghanis have been unearthed in excavations at Aihole (the sixth century AD) in Karnataka.[33A] An old stone oil mill with an inscription to say that it was set up in 1145 AD in Karnataka state by one Asakka-gavunda is stated to still exist.[34] Three types of oil mills of that period are described,[34] driven respectively by oxen, by hand and (somewhat intriguingly) by foot. Sesame was the seed commonly extracted in the north, and dried coconut (copra) in south India.[34] The *Arthasastra* casually notes a revealing list of the oil-bearing seeds extracted about 300 BC in oil mills: the sesame, linseed, safflower, mahua, neem, ingudi (*Balanites aegyptiaca*, today called hingot), kapittha (*Limonia acidissima*, the wood apple) and an unidentified seed called kusamra.[12b] Nowhere is the nature of the oil-milling device even briefly described.

Nai and Ennai

These are words used in the languages of south India for oils and fats, and their origins seem to have a bearing on oil-crushing. The coconut is of very ancient occurrence in south India. The word for coconut oil is *ngai* in the Nicobar Islands, *niu* in Polynesia and *niyor* in Malaysia, and the Tamil *nai* (nei) is believed to have arisen from these.[32] Coconut oil is sometimes semi-solid, and it would seem that the term *nai* came to denote any semi-solid fat, like butter (ven-nai) or ghee (simply nai).[31] The sesame seed was then called *enn* as is noted in the Tamil grammar *Tolkappiyam*[29] written about the start of the Christian era, and sesame oil was first termed *enn-nai*.[27b] Later this word became a generic term for all liquid oils, exactly as had happened earlier with the Sanskrit word *taila* for sesame oil. Another name for sesame also mentioned in the *Tolkappiyam* is *ell*,[27c] which is also its present name. Sesame oil was therefore designated ellu-ennai, coconut oil thenga-ennai, and so on. It is of great interest that the Greek word for oil, elaion, also resembles the early Tamil term ell.[30]

7.2 Ghani Design

Characteristic Features

General features: Sugar cane crushing, as we have seen, shares a common ancestry with oilseed crushing. William H. Sleeman was an administrator known for his part in bringing to an end the ritual killing of innocent travellers by a professional group called thugs. Writing in 1836 about Saugor, in Rajasthan, Sleeman says: "Sugar-mills are made like a pestle and mortar, the mortar being cut out of the hornblende (black) rock and the pestle out of wood. . . The driver sits upon the end of the horizontal beam to which the bullocks are yoked; and in cold mornings it is very common to see him with a pair of good hot embers at his buttocks resting on a little projection made behind him to the beam for the purpose

of sustaining it."[33] This is an apt description of one form of the ghani of today.

Certain features are common to all ghanis (Fig. 18). The mortar or aukhali can be made of either stone or wood, the preferred hardwoods being blemish-free logs of tamarind, neem, jack (*Artocarpus heterophyllus*), baheda (*Terminalia belerica*), babul (*Acacia arabica*), sirish (*Albizzia lebbeck*) and sal. The mortar is the receptacle for the pit or fatcher, termed khand, which can be of several designs. Since the huge log is valuable, it is fairly common to design the pit as a sleeve which sits snugly in the block, and can be replaced far more easily and cheaply when worn out by use. Generally the pit is not very wide, since on this, and on its depth and slope, will depend the inclination at which the pestle will rotate. At the base of the pit is the drain pipe to lead off oil, a feature missing in south Indian ghanis.

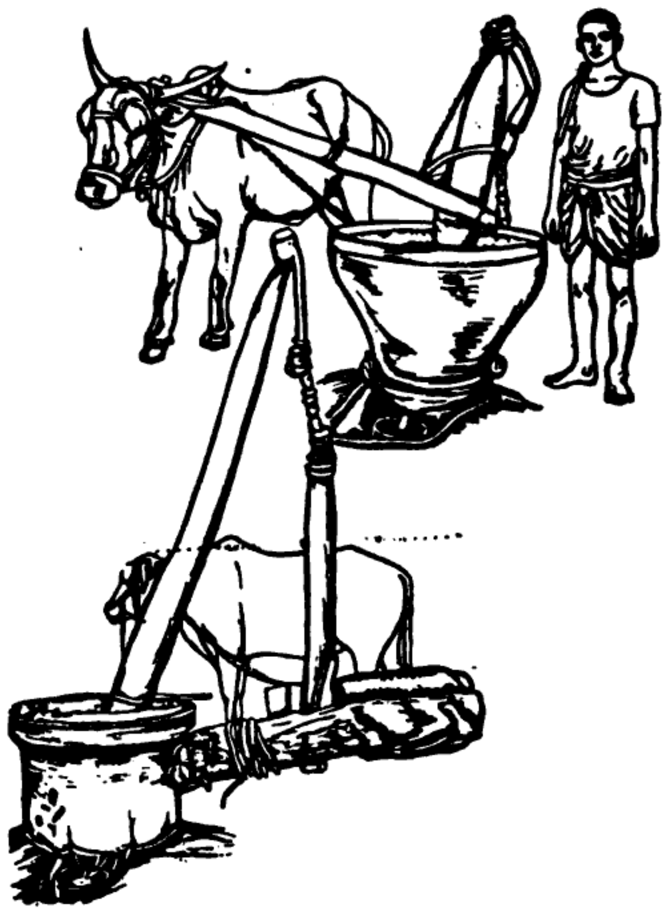

Fig. 18. Traditional ghanis for crushing safflower seeds (short pestle) and mustard seeds (long pestle) (Courtesy: Khadi and Village Industries Commission, Bombay).

The pestle or lat is fashioned by hand, or on a lathe, from a hard wood like baheda or sirish. It varies greatly in both length and thickness, but must be so designed that it can be totally lifted out between crushing

operations. The slant of the pestle generally matches that of the pit so as to ensure maximum contact and friction. This is also necessary to draw seed from the base up the sides of the pit, where the size-reduction of seed and the crushing of oil actually occurs by lateral pressure. The tip of the pestle is usually swollen or even bulbous, to ensure as little dead space as possible in the pit. The lower end of the pestle is sometimes clad with metal strips nailed on, so as to increase pit friction and also save wear and tear on wood. Some ghanis have a brush or sametani, hanging from a nail on the beam post, to brush seed or oilcake from the flat edge of the mortar back into the pit. This is not however a common attachment, and usually it is the artisan who sees to this, using the edge of his palm.

The vankadi literally means curved wood, but is often a heavy angled piece, which rests on top of the pestle and serves to push it down. For reasons of convenience it is frequently made up of two pieces, which are pinioned or tied together in some way, thus also permitting their unhooking when the pestle has to be lifted out. The top of the curved wood carries on its underside a scooped-out hollow which fits on top of the narrowed end of the pestle, and is frequently lubricated with soap or an oily rag.

An important and complex constituent is the load beam or bhojpat. One end of it usually rests on the outside of the ghani mortar, either high or low depending on local design, usually riding in some sort of a groove round the outside of the barrel. The other end of the bhojpat is attached to the animal or animals. This can be directly in the form of a yoke, or indirectly through metal chains attached to the wooden halter. The curved wood is attached to the bhojpat somewhere along its length; there is also some free length, on which stone weights may be applied, or on which the human operator can sit either on his haunches or with his legs dangling down. The design attempts to provide maximum working comfort for the animal, through adjusting the length of the load-beam, the weight applied, the degree of friction against the outer groove in the mortar, and the type of yoking arrangement.

Pressure on the animal must be lateral to ensure an upright posture for easy forward movement. Sometimes the load-beam is made very long, and sometimes it ends in a curve which rides on the neck of the animal. Use of a chain for yoking permits a more flexible arrangement. Bullocks, male buffaloes, and camels are the usual beasts of burden, but female animals are sometimes used. Even human labour for small ghanis is known to be employed in Kerala,[38] Orissa[69] and West Bengal.[41] While in prison in Coimbatore, an oil mill in the jail premises (which still exists) was drawn, as part of a sentence to hard labour, by a political activist against British rule; this was the shipping magnate V.O. Chidambaram Pillai, who carried this 'distinction' with him ever after (Plate 20).

Small ghanis can be installed under the domestic roof, and large ones outside, in the open or under cover. In many villages (this was more common in the past than now), several ghanis would work in groups, these

being generally hired out by wealthy merchants to poorer artisans.[39a] About 1900, the small town of Valavanur in the South Arcot district of Tamil Nadu was reported to house 1000 working ghanis, and even as late as 1960, the village of Vengalapuram, also in Tamil Nadu, had 350 ghanis in place.[40]

The life of ghanis is short. A wooden ghani can take about 2000 charges, and will therefore last about a year, with 10 changes of pestle. When the pit becomes wider, a thicker pestle has to be employed. Discarded mortars can be employed as feeding troughs for animals, or chopped down into smaller wooden articles. Wooden pestles when discarded can yield household posts or furniture. Stone ghanis have a life of perhaps 30 years if fully fashioned of stone, but the fatchers, if made of wood, need replacing annually.[45e]

Regional Ghani Types

When the ghani was first being redesigned in the thirties, a survey showed that the various regional designs fell into four broad categories.[36b,37] The will now be described.

South Indian chekku: This is frequently a large ghani with a capacity of 35 to 40 kg a charge, and is usually made out of the local granite stone. The wooden halter goes on the necks of two animals, and is chained to the load beam, which is usually very long and curved. Since it has a tendency to ride up, it is anchored in a strong outer groove on the mortar. Usually two attendants are required, one for the animals and another at the mortar operation itself. Friction is high, and the resulting whining noise is considerable. The south Indian chekku has no drain pipe for oil, which collects in the pit and is mopped up after the operation. The life of a stone chekku is stated to be 40 to 50 years before the pit becomes too large to be used. Occasionally wooden mortars are also used in the south. These are necessarily small, and so also are the pestle and load-beam.

Gujarat-Maharashtra ghani: Made of wood, and of capacity 8 to 15 kg, this type of ghani is designed for one animal. The yoking arrangement is well-designed and comfortable. The operator usually rides on the beam and is accordingly less attentive to the needs of the pit, like spillage and water-addition. There is always an oil outlet drain, but in consequence sediment and even water come through, and subsequent settling of the oil is essential for clarity.

Bengal ar Diamond Harbour ghani: These are so called from the port locality of Calcutta where they once operated. The pit capacity is small, usually 5 to 10 kg or even smaller, though the mortar itself may be large. Slow pestle movement with judicious wetting is employed, to yield from rape-mustard seeds an oil of piquant flavour caused by release into it of pungent isothiocyanates derived from precursors present in the seed. Because of the long operation, the animal may even be changed half way, and it is frequently blindfolded. In 1941, about 10 per cent of the ghanis in Bengal reportedly used human, generally female, labour.[41] The pestle is

usually tall and only very slightly inclined, often just 7° from the vertical, and the wear is heavy at the base, which is thereafter cut off and reshaped for re-use. Because of small size, a considerable cake thickness builds up in the chest, and the oil content in cake is frequently high.

Punjab ghani: Again these ghanis are small, taking about 5 to 8 kg per charge. The pestle is short and squat, and the pressure developed is low. A thick cake of high residual oil content forms in the shoulders.

Comparative performance of ghani types: Data on actual performance of ghanis in various parts of India crushing sesame seed, given by Chaudhuri and Selvaraj,[37] are shown in Table 9. These have been recalculated for the present purpose. The big chekkus of south India take 31.0 to 5.0 kg each time, and turn out to be the most efficient of all in terms of oil crushed per hour (2.87 to 0.75 kg), probably employing two bullocks. Everywhere else only one animal was probably employed. In the ghanis of western India, the charge is small (9.5 to 5.8 kg), and the rate of oil extraction is high at 2.15 to 0.72 kg. The small ghanis of eastern India, crushing mustard seed and copra, have hourly extraction rates of just 0.84 to 0.60 kg, and the even smaller ghanis of north India have out-turns below even these figures. The large south Indian ghanis make a good showing, but the high rate in the smaller units of western India show that design can also be of importance. The extraction of oil is up to 50 per cent in the south Indian chekku, and mostly between 40 and 45 per cent in the ghanis of western India.

7.3 Ghani Operation

Nature of Oil Extraction

As in a screw-press, an expeller or a hydraulic press, it is the application of pressure that effects the expulsion of oil in a ghani. This pressure is brought into play by ghani design, and the actual degree of oil expulsion achieved depends on this, and on the skill of the operator, the judicious additions of water at various stages, and the generation of heat through friction. Some of these components may now be considered further.[36,37,42,43,44]

Factors in Ghani Operation

Generation of pressure: A major component of the pressure at work in a ghani is the load on the beam, which is then transmitted to the top of the pestle by the curved wood. This has been estimated to be of the order of 115 to 160 kg. Fibrous oilseeds like linseed and copra need more than this, but the animal would have to be strong enough to support it, so by way of partial compensation the crushing time is prolonged. Pulverisation of seed should ideally take about a third the total crushing time, but can be prolonged if the load is insufficient, the seed too wet, the bullock too slow, the seed feeding uneven, or the disposition of the ghani components faulty.

Table 9. Performance of various ghanis in crushing sesame seed[37]

Location of ghani	Crushing details			Efficiency			
	Total seed crushed kg/day	No. of charges per day	Av. qty per charge kg	Total working period hr	Oil extracted %	Oil extracted kg/day	Oil extracted kg/hr
South India							
Tiruvannamalai (Tamil Nadu)	62	2	31.0	8	37	22.94	2.87
Chittoor (Andhra Pradesh)	45	2	22.5	8	35	15.75	1.97
Cuddapah (Andhra Pradesh)	37	3	12.3	11	47	17.39	1.58
Kozhikode (Kerala)	26	2	13.0	9	49	12.74	1.42
Pithapuram (Andhra Pradesh)	15	3	5.0	10	50	7.50	0.75
Western India							
Rajkot (Gujarat)	46	8	5.8	13	44	20.24	1.56
Sabarmati (Gujarat)	41	5	8.2	8	42	17.22	2.15
Pandarpur (Maharashtra)	38	4	9.5	8	26	9.88	1.24
Bombay area (Maharashtra)	30	4	7.5	8	45	13.50	1.69
Bhusaval (Maharashtra)	18	3	6.0	10	40	7.20	0.72
Eastern India							
Badadangal (West Bengal)	21	2	10.5	8	32	6.72	0.84
Comilla (West Bengal)	21	4	5.3	12	34	7.14	0.60
Bhadrak (Orissa)	18	3	6.0	9	31	5.58	0.62
North India							
Jalandhar (Punjab)	17	2	8.5	7	38	6.46	0.92
Bijnor (Uttar Pradesh)	16	4	4.0	12	37	5.92	0.49
Chopra (Bihar)	15	6	2.5	12	33	4.95	0.41

The inclination of the pestle in the pit has been shown to be important to the pressure exerted. Too small an inclination will lessen pressure, and too great a slope will result in a lateral pressure component that will push cake back into the pit instead of holding it in the shoulders to be crushed. A pestle slope of about 21° from the perpendicular was experimentally determined to be optimal. The thickness of the pestle is also clearly a determinant, and a thick pestle relative to the pit diameter will result in greater pressure and a thinner build-up of cake and better oil expulsion. Similarly the swollen end of the pestle must match the curvature of the cavity, but still leave room for oil to accumulate. In practice, numerous pit designs have come to be evolved all over the country in an attempt to facilitate ghani operation (Fig. 19). A rounded base surmounted by a chest that tapers slightly outwards is perhaps the commonest, along with a club-like pestle that has a swollen tip. Also, oilseeds like the groundnut, which are low in fibre and high in oil, need a lesser pit curvature than fibrous oilseeds like rape-mustard and copra. Both traditional wooden pits and pestles were turned on lathes, or chiselled from logs.

Fig. 19. Replaceable wooden pits used in ghanis of various designs (Source: J.P. Patel[42]).

The pressure exerted in a ghani at the point of maximum contact in the chest is given as 10 kg/sq cm.[45a] For comparison, this is about one-third that developed in a small expeller, and one-tenth to one-hundredth that in larger expellers.

The role of water: Pressure is applied both initially to bring about the disintegration of oilseeds in a ghani, and later to achieve expulsion of oil. In both these phases, a considerable role is also played by added water. Water addition is done in stages, and while about 6 per cent of total water on the weight of seed is usually employed, the natural water content of the oilseed, the extent to which it has been dried, and whether the season is wet or dry, will influence the quantity of water added by an experienced ghani operator.

Right at the start, soon after the seeds have been added, the first addition of water is made to give the pestle a grip on the dry seed and prevent it from simply slipping around. When actual seed grinding com-

mences, the frictional heat generated promotes further seed repture. If too little water is added, the seeds will drop whole into the pit, and the pestle may even rise into the chest.

The second addition of water is judged with care: if done too soon, seed pulverisation and cake formation will be retarded, and whole or partly-crushed seeds will lodge in the cake mass, and remain uncrushed. The second instalment of water, with frictional heat now present, serves to cook the reptured seed, denature and coagulate the protein, and displace oil from the seed. To test the water status of the mass in the ghani, the artisan will squeeze some of it into a ball in the palm of his hand: if the water is sufficient, the mass will not fall apart when released, but if either too little or too much water is present, the mass will crumble. Corrective additions of either water or seed are now made, and the animal goaded to resume its orbit. At a certain point with the animal in brisk motion, a mass of frothy oil rather suddenly floods the ghani surface, and the operation is vigorously continued for a few minutes longer to complete the crushing.

Water is sprinkled a third time just before the oil is due to be removed or drained from the pit. This is said to clarify the oil, probably by hydrating and precipitating gums and phospholipids. The foam also settles on water addition, and this is even believed to cause water that is in suspension to settle.

As a fourth and last addition, the artisan passes a wet hand lightly over the surface of the cake to free it of adherent oil and give it a sheen, just before the latter is dug out of the pit using a crowbar. This should be done quickly and carefully without damaging the wooden walls of the pit.

Principle of ghani oil expulsion: The violent release of oil at a certain point which occurs in ghani operation is also characteristic of the Skipin process of oil extraction using water displacement that was developed in Russia, in which the water content is first carefully adjusted to lie between the rather narrow limits of between 14 and 18 per cent.[47] Further, the solid seed mass in Skipin extraction suddenly changes its nature to become coherent and granular, exactly as happen in the neck of the pit in the ghani operation. It has been suggested that similar physico-chemical principles operate.[46] However, it has also been argued that the proportion of water, 3 to 8 per cent, needed in the ghani to release oil is much less than in the Skipin process, and indeed closer to that used in expeller pressing. In practice in the ghani, the oil released cannot drain away because of the design of the unit and simply gets reabsorbed into the cake, and more water is necessary only to permit draining of the oil, and not for its release.

The role of heat: The movement of crushed seeds against the sides of the ghani pit releases frictional heat. This aids the disintegration of seed cells, and causes the release and coalescence of oil by reducing its viscosity. Brisk movement of the animal without too many pauses maintains heat generation and prevents its dissipation, aided by the fact that the

wooden unit is a poor conductor of heat, stone being less so. Sometimes, especially in cold weather or for viscous oils like castor or mahua, a burning torch is passed over the material in the pit to furnish external heat.

ACTUAL CRUSHING

Representative procedure: This may be described for a batch of 10 kg of sesame seed. About 7.5 kg of seed is placed in the pit, and the animal set in motion. About 750 ml of water is kept handy. In a few minutes the seeds start to rise into the chest, and the first addition of 180 ml of water in the chest and 120 ml in the pit is made. Operation is resumed, and in a few minutes most of the seed will be seen to be crushed. Now the second lot of 300 ml of water is poured evenly round the chest where the bruised material is lodged. This is now raked with a crowbar and broken up by hand. The rotating operation is resumed and the remaining 2.5 kg of sesame seed, which has been kept spread on the flat rim of the pit, is now evenly pushed in even as the animal keeps moving. As the crushing proceeds, the operator tests the adequacy or otherwise of water by forming a ball of the material in his hand, and seeing whether it retains its shape through proper coherence. Sometimes a little extra water, or some extra seed, may be needed for the right moisture ratio. The cake may now be lightly prized away from the sides without stopping the animal.

Typically, after some 75 minutes of operation, a flood of frothy oil suddenly appears on the surface. The animal is kept briskly moving, and the third lot of about 100 ml of water is sprinkled evenly over the surface. Motion is stopped, and the pestle allowed to rest to permit oil and sediment to settle. The last lot of water, 20 to 30 ml, is now brushed by hand over the cake surface to free it of adhering oil, and the animal makes a few turns for the same purpose. The curved wood is now unhooked, and the freed pestle lifted out and set aside. Sesame oil collected at the base of the pit is either drained out through the outlet pipe, if any, or mopped up using a string mop or a large piece of cloth, which is then wrung out by hand into a tin, from which the oil is decanted after it has settled. The cake is dug out, using a crowbar, in the form of thick curved slabs.

Practical difficulties: A cake thickness of 1 cm at the top of the pit, and about 2 cm below, is considered to denote satisfactory ghani operation. Cake thickness is important in that it reflects the efficiency of oil extraction. Too thick a cake may result, apart from any design deficiency, through improper additions of both seed and water, or inattention by the artisan.

Poor cake formation has another consequence, that of causing the pestle to rise and even topple out of the pit. If this happens with an oilseed that is known to be suited to ghani crushing, the animal is slowed down; in consequence the material in the pit has a chance to be pulverised, frictional heat is generated and the cake can rise into the chest and not lodge below. Sometimes well-formed cake from an earlier operation, or

even straw is added to the same end. Certain oilseeds like pisa (*Actinodaphne hookeri*) and khakan-pilu (*Salvadora* spp.) are intrinsically unsuitable for ghani crushing, and some groundnut or castor oilcake of high granularity is added as a corrective during crushing. Use of a surfactant like alkylbenzene sulphonate has also been found to be effective.[81,173] Other oilseeds that cannot be ghani-processed are the cottonseed, sal, dhupa and nahor, either because they form no cake, or have too low a fat content, or carry a high-melting fat. Soybean and ricebran are too low in fat to be pressed in ghanis.

7.4 Modern Attempts to Improve Ghani Design

Nationalist Aspirations

The stages in the past by which the ghani evolved in its present form are not known, and even an age of 500 years casually suggested for its present design is purely speculative.[43] About 50 years ago, an All-India Village Industries Association was established at the instance of Mahatma Gandhi at Maganvadi near Wardha. Dr. J.C. Kumarappa, a Gandhian economist was its Director, and Jhaverbhai P. Patel, an engineer, was put in charge of the ghani oil sector. He systematically studied the types of ghani in various parts of the country, and built models to examine the scientific principles behind its working. In 1939 Patel produced his first book, called *Oil Extraction*; Gandhiji reviewed it in his newspaper, the *Harijan*, on September 2 of that year, and wrote that Patel had "made improvements which he claims have lessened the labour of both men and animals who work at the ghani and at the same time have increased the output of oil", adding that "the oilman has disappeared or is fast disappearing." In 1943, the third edition of this book appeared, and the Wardha ghani, a design improvement over the earlier Maganvadi ghani, was fully described with engineering drawings.

The Association was first renamed the All-India Khadi and Village Industries Board in 1953, and a few years later the Khadi and Village Industries Commission (KVIC). Work on improving the efficiency of the ghani went forward continuously, and many other processing auxiliaries and oil-expelling devices were also developed. These developments will now be recounted.

Early Improvements

The rotary: This was developed as early as the turn of the country, and was an attempt to adapt the ghani principle to the use of power from an oil engine or electricity. It was obviously designed not for the use of the village artisan but for urban industry. First came the single rotary, with the geared drive placed below in a pit, a stationary pestle anchored in place with a chain, and an outlet spout for the oil. Soon batteries of such rotary units run from a common shaft came to be installed in oil mills, particularly for rape-mustard crushing along the Ganges valley, and for

copra crushing in Kerala. Crushing of these two materials in rotaries is still much in vogue. Rotary crushing of groundnut[39] and linseed,[52] which prevailed in the thirties and the forties, has now been replaced by expeller operation. The rotary principle was to be employed by the KVIC much later when the use of electricity was adopted.

Metal ghanis: A ghani made of sheet-iron was tested out in Wardha,[49] only the pestle being made of wood. The hollow space between the iron pit and iron body could be filled with hot water generated below using firewood.[50] Liquid oils were found to be best expressed at 60° to 70°C. Solid fats like coconut, mahua and neem each needed a different optimum temperature, which could be determined by actual experiment. Seed crushing being exothermic, extra heat was not required once the operation had started. Oil yields were high, extraction time was lowered, animal strain was reduced and the cost of the hot water was marginal.

In another variation, the pit was cast instead of being welded from sheet,[49] with similar advantages and a wide oilseed range.

Though not made wholly of metal, a heated ghani of 18 kg capacity devised by the Khadi and Village Industries Board of Gujarat state utilised a thick metal plate only for the base of the pit, and heating from below by steam.[49]

The Wardha Ghani

The Maganvadi-Wardha ghani: Five desiderata were used to evaluate six types of regional ghani designs. These were: (a) high oil out-turn, (b) large seed capacity, (c) minimal crushing time, (d) minimal use of both animal and human energy, and (e) low capital recurring cost. Based on these needs, a ghani was designed (Fig. 20) and models built for experimental evaluation and further improvement. The Maganvadi ghani of 1940 had a capacity of 7.2 kg, a total mortar height of 160 cm (of which 90 cm was buried in a concrete foundation), a diameter of 68 cm, an external iron loop around the mortar for strength, and a carefully-positioned drain pipe. The optimum pestle slant of 20° to 22° determined experimentally was achieved through a similar slope on the pit wall, and the length of the neck represented a balance between the shortness desirable for cake circulation and the length needed for efficient crushing. To minimise dead space, the bulbous end of the pestle and the rounded base pit shared a common arc (Fig. 21). The pestle was 230 cm high. A sweep to push material down from the pit was included.

The curved wood was designed as either a single piece or two pieces. The load-beam struck a balance between length and speed of operation, and was placed high against the outer mortar surface. The animal was hitched to a peg provided at the end of the load-beam. The yoke was curved to reduce strain on the animal.

The Wardha ghani arose about 1954 from experience with the Maganvadi type. It was in two standard sizes of 5.5 and 9.1 kg, and had an

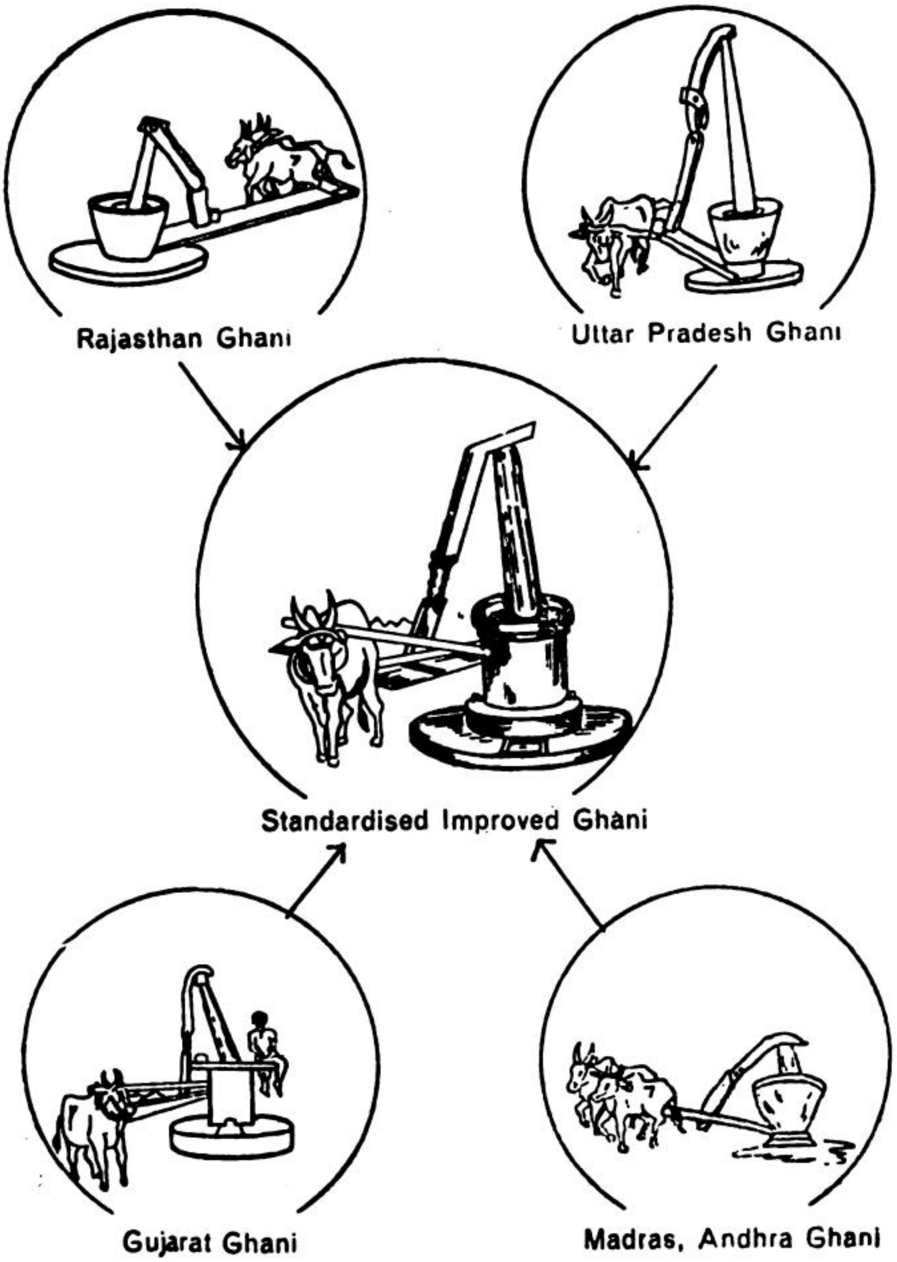

Fig. 20. The Maganvadi-Wardha ghani incorporated the best features of various regional designs (Courtesy: Khadi and Village Industries Commission, Bombay).

iron drum holding the fatcher, a high pestle, and a roller bearing where the angled piece rested on the pestle top.

Table 10 shows performance data on the Wardha ghani. Oil extraction is high and crushing time short, making for cost reduction and working efficiency. Strain on the artisan was reduced through the provision of automatic stirring and an oil drain. Moreover, the pestle did not have to be removed after each operation, and one person could tend two ghanis.[37,42b] The fitting of ball-bearings in the pestle cap reduced animal effort, as did the provision of a trenched track. Formulae were worked

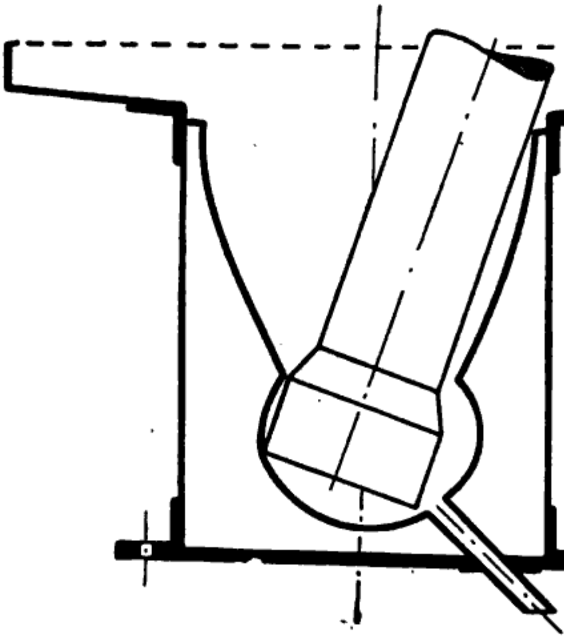

Fig. 21. Mortar of improved ghanis, showing the disposition of the end of the pestle in the base of the pit (Courtesy: Khadi and Village Industries Commission, Bombay)

out to adjust the capacity of the Wardha ghani to suit the size and strength of the animal. Standard replacements could readily be had by the artisan.

Table 10. Performance data of the Wardha ghani[46b]

Seed crushed	Capacity per charge kg	Oil extraction %	Time taken per charge mts
Sesame	8	45	75
Groundnut	8	45 to 49	60
Coconut	8	55 to 62	45
Mustard	6	30	60
Yellow mustard	7	30	60
Mahua	7	35	60
Castor	8	40	60

In 1958, the results of 600 observations on crushing sesame seed, 400 on groundnuts and 600 on linseed using six Wardha ghanis provided with roller ball-bearings were published.[53] The usual standard deviation for percentage oil extraction was ±2.5, and the range ±1.5 to 5.0. Between the six ghanis, mean extraction values for any oilseed usually differed only by 1 per cent, the maximum recorded being 1.9 per cent. Clearly the Wardha ghani was a well-standardised unit, in terms of repeatability and

reproducibility. A study using Wardha ghanis in 1964[54] to crush sesame seed and linseed examined the relationship between batch size and period of crushing. Prolonging the crushing time did raise yield, but reduced the number of charges that could be handled each day, with no overall increase in out-turn. What was really needed, if the artisan was to benefit economically, was to greatly increase the crushing capacity of the ghani.[36d]

Working experience with the Wardha ghani showed up certain drawbacks.[37] The main one was the very long length (1.8 to 2.5 metres) of the pestle. Wooden logs of this size were difficult to find, and moreover a tall shed was needed to house the ghani. The pestle length was accordingly shortened, but this meant also a total redesigning of the pit and other components in later units.

Modified Wardha ghanis: In the Kallupatti ghani,[37] the pestle was shortened (1.5 m), and the entire weight of the load-beam was brought to bear on the pestle head. Steel plate was used in place of wood to make the tie rods of the load-beam. The pestle cap was separately made of wood, and fitted with two tapered roller bearings.

The Warangal ghani[37] was a large one (15 kg), made not with a single wooden log but using cheaper wooden strips.

The Nutan ghani was of smaller capacity than the Wardha, and had a shorter pestle (1.8 m). The length of the load-beam was reduced, making for compactness, and the load was suspended at the very end.

Upgrading traditional ghanis: KVIC soon undertook to improve traditional stone or wooden ghanis by fitting them with replaceable Wardha parts.[42c] Sometimes the inner portion of the mortar had to be modified to provide a platform wall and a flat stirrer margin. By 1958, some 5,800 improved Wardha ghanis were at work,[42d] and by the next decade, about 32,500.[55] At this point power-driven ghanis had been developed, and the 10,000 new installations by 1981 consisted mostly of these as they were more widely available. Acceptance of power ghanis in the north of India was better than in the south,[37] where the small size of the improved ghanis was compared unfavourably with the large stone ghanis that existed. Traditional artisans were also wary of their skills becoming redundant through mass manufacture of components.

Electrically-powered Ghanis

The advent of electric power: For long, only animal or human power was considered conceptually appropriate for village industries, and in one experiment, a bullock was even tried out to run an oil expeller.[56] In 1962, it was pointed out that there was nothing against machines as such, since the oil ghani itself was a machine, and so were the *chakki* and the Persian wheel.[57] So long as machines did not master man, even power could be used, as in the powered charka for hand-spinning. Powered units should be capable of meeting demand without creating unemployment.

The escalating cost of employing animals was also evident.[45a] Bullocks represented 70 per cent of the overheads, which accounted for 10 to

15 per cent of costs in the oilseed crushing industry (raw materials constituted the remaining 90 to 85 per cent), so profits were negligible. Electric power was to be had at barely one-fifth the cost of animal power. Without better margins, there was little hope of the ghani surviving at all.

In December 1968, the Technical Experts' Committee of the First Saranjam Sammelan held at Rajkot, after debating the issue, recommended the use of electric power for oilseed crushing while stressing that the consumer preference for flavour and taste should be safeguarded.[37,45a] As one consequence, a power-driven ghani was designed. As another, power-driven devices were developed to motorise traditional ghanis whatever their size.[58] A typical overhead drive consisted of a 2 hp motor with an rpm of 1440 used with a belt and pulley system at a 120:1 ratio to reduce the rotation to a convenient 10 to 12 rpm. This overhead drive could be fitted to the beams of the house if the ghani was located indoors, or on concrete pillars and beams built for the purpose when it was outdoors. A loan of Rs. 17,400 for thus powering two adjacent ghanis was instituted by the KVIC in 1980.[58]

Rotating barrel power ghani: The possibilities of both a rotating pestle, as in the traditional ghani, and a rotating mortar, as in the long-established rotary, were both considered in adapting the ghani to power. At Wardha, the Jamnalal Bajaj Central Research Institute in 1969 devised a wooden pestle and a rotating wooden mortar (driven by pulleys through a three-stage gear), a spring and handwheel for control of pestle pressure, a stirrer for the seed meal, and a small single kettle for separate steaming of the seed material. A mortar speed of 20 rpm was found convenient.[37]

Alongside, designs had been improvised in the field by local mechanics for rotating the pestle from the top using power,[45a] employing differential crown and pinion gears discarded from trucks. These were examined by a KVIC Committee who recommended for design development the pestle-rotating device. This was familiar to traditional artisans, and moreover it was cheaper to build than the mortar-rotating system and consumed less power.

Overhead power ghani: A pestle-rotating unit was ready in 1972, and was essentially a Wardha ghani driven by power from above through belts and pulleys (Fig. 22). Though to ensure sturdiness the barrel was made of iron or cement, the fatcher was a wooden insert and the pestle was also made of wood to preserve the flavours of ghani-pressed oils which consumers favoured.[37] A high capacity of 15 kg per charge was possible through use of power, and was recommended for better economy. The curved piece that connects the pestle to the load-beam in a traditional ghani was replaced with a spring-adjustable pressure arrangement to exert lateral pressure at 90° on the pestle. The 2 hp, 1440 rpm motor used was reduced in three stages using both pulleys and a crown and pinion gear so as to give a pestle rotation speed of 12 rpm. The design, though itself based on trials with model units, was again tested in 12 places using different seeds, and 150 units of the modified model were again disbursed for further

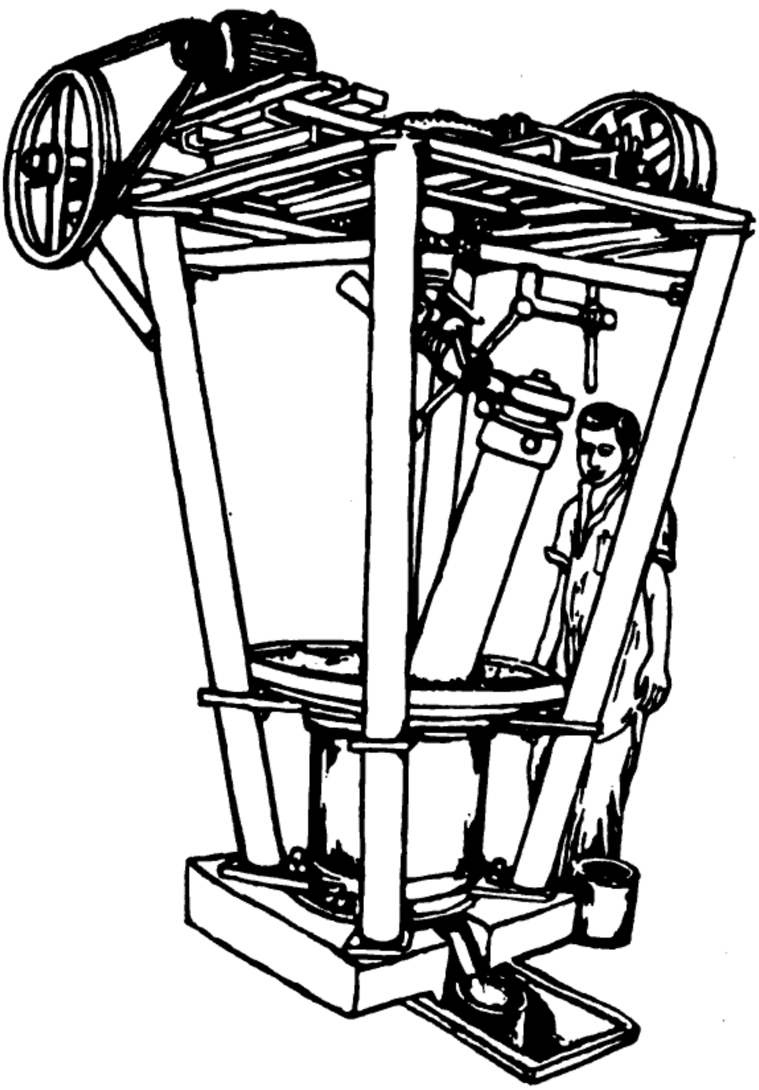

Fig. 22. Overhead power ghani (Courtesy: Khadi and Village Industries Commission, Bombay)

trials. Eventually 350 units were manufactured and tried out, again modified, and evaluated by a committee before the design was finally approved for manufacture. Thus the original area requirement of 3.7 sq m eventually came down to just 0.56 sq m.

Table 11 shows data obtained on the overhead power ghani during the field testing phase. The percentage oil extraction is always higher, by a maximum of 3.6 per cent, than in a traditional unit, the time of crushing can even be halved, and the cost of crushing is one-eighth. So striking was this achievement that in the next decade, some 12,000 of these units were installed all over the country.[59]

Some drawbacks appeared with time.[60] The metal or wooden superstructures were elaborate and expensive. A tonne of scarce cement was needed for the foundation. Trained persons were needed for installation, and the slightest error in alignment resulted in a breakdown. The vibration

Table 11. Comparative performance of traditional bullock-driven ghanis and overhead power ghanis[a]

Place of crushing, and seed crushed[b]	Bullock-driven ghanis				Overhead power ghanis			
	Capacity kg	Extraction %	Time taken hrs mts	Cost Rs/qtl	Capacity kg	Extraction %	Time taken hrs mts	Cost Rs/qtl
Sesame								
Madurai (Tamil Nadu)[c]	12-14	45.0	14=56	11.06	12-14	45.0	12=28	2.00
Kanchipuram (Tamil Nadu)[c]	10-14	40.0	17=42	8.08	10-14	42.3	8=08	1.70
Delhi (Delhi State)	10-12	43.0	20=00	22.00	10-12	46.6	17=38	2.34
Jaipur (Rajasthan)	—	—	—	—	20-25	45.0	15=20	2.00
Gundi (Gujarat)	—	—	—	—	8-9	45.8	16=00	2.50
Mustard								
Barama (Assam)	5-06	30.5	83=08	3.20	7-9	30.9	20=09	N.A.
Mawana (Uttar Pradesh)	9-10	34.2	47=09	22.00	9-11	36.2	27=01	2.50
Gaya (Bihar)	10	35.5	41=25	8.00	10-11	37.0	21=14	3.44
Copra								
Kottar (Tamil Nadu)[c]	9-11	61.0	15=45	16.00	9-11	61.0	14=10	2.00
P.K. Vila (Kerala)	15-20	62.0	30=00	15.00	15-30	63.0	12=00	3.00
Safflower								
Hyderabad (Andhra Pradesh)	16-20	48.9	7=42	5.00	16-21	49.9	6=22	0.70

[a] P.V. Gujarathi, Ref. 45a

[b] Same lot of seeds used for bullock and power ghani crushing in each location. Between locations, seeds would of course vary

[c] Two bullocks employed in these runs. All other runs employed only one animal

caused by the overhead drive caused excessive wear and tear on all the movable parts and especially on the pinion.[45a] The tempering of the shaft became weakened when the pinion was welded to it. Women found it difficult to understand and operate the overhead power ghani, and something simpler was needed.

Portable power ghani: A private firm, Vivek Engineers, Vellore, Tamil Nadu, came up about this time with a ghani that had a rotating barrel, and KVIC undertook its evaluation on several oilseeds at seven locations within its own network.[59] While mortar rotation was found to be advantageous, the design itself showed scope for improvement. The wooden pit was not replaceable, the solid wooden mortar was prone to develop cracks, the fastening of the mortar to the base-plate tended to loosen, and the mounting of the bottom plate on the vertical spindle was clumsy. The drain pipe was unsuitable for processing safflower kernels, and the pressure mechanism inadequate for mustard and linseed.

A new design (Fig. 23) was evolved by KVIC at its Dahanu workshops.[59] The excellent iron drum and replaceable pit from the Wardha and overhead power ghanis was adopted, and the metal drum could easily be bolted to the base plate. Mounting of the spindle on the base plate was simplified so as to permit easy detachment of the drum when required. The drain hole was enlarged to a 2.5 cm diameter for easy outflow of oil without clogging. A cake breaker was added. Use of a stronger pressure spring permitted higher pressures for use with difficult oilseeds. An ammeter, voltmeter and pilot lamps were provided to alert the artisan, and ball bearings were fitted in the rollers.

The new unit and the original Vivek ghani were evaluated at the Third Saranjam Sammelan held in New Delhi in March 1983.[61] Each was felt to offer some advantages, and the artisan was allowed his choice. A recommendation that the good features of each be merged in a new design to be attempted by the KVIC gave birth to the portable power ghani.

In this, wooden pieces fixed in an iron drum were employed to fashion the fatcher. Some 66 standard replaceable parts available commercially were employed. A drainage tray with an outlet that could be spring locked was an added feature. A stirrer-sweeper was incorporated. A major design feature was that all moving parts were enclosed, and that safety devices were incorporated to prevent breakdowns. Placing the drive mechanism on one side on the ground served to absorb both weight and vibration. The drive was connected to the mortar, and the pressure on the stationary pestle was adjustable with a screw. The crown pinion was inverted so that the crown was above, serving to reduce damage, protect the unit from dirt and dust, and allow for continuous greasing from an oil can placed below it. The pinion shaft and bearings were also enclosed. The unit was extremely compact, just 114 cm by 122 cm and 150 cm tall, light in weight (530 kg) and therefore easily portable. Eliminating the need for foundations meant that no cement was needed, and that the unit could be set up in a

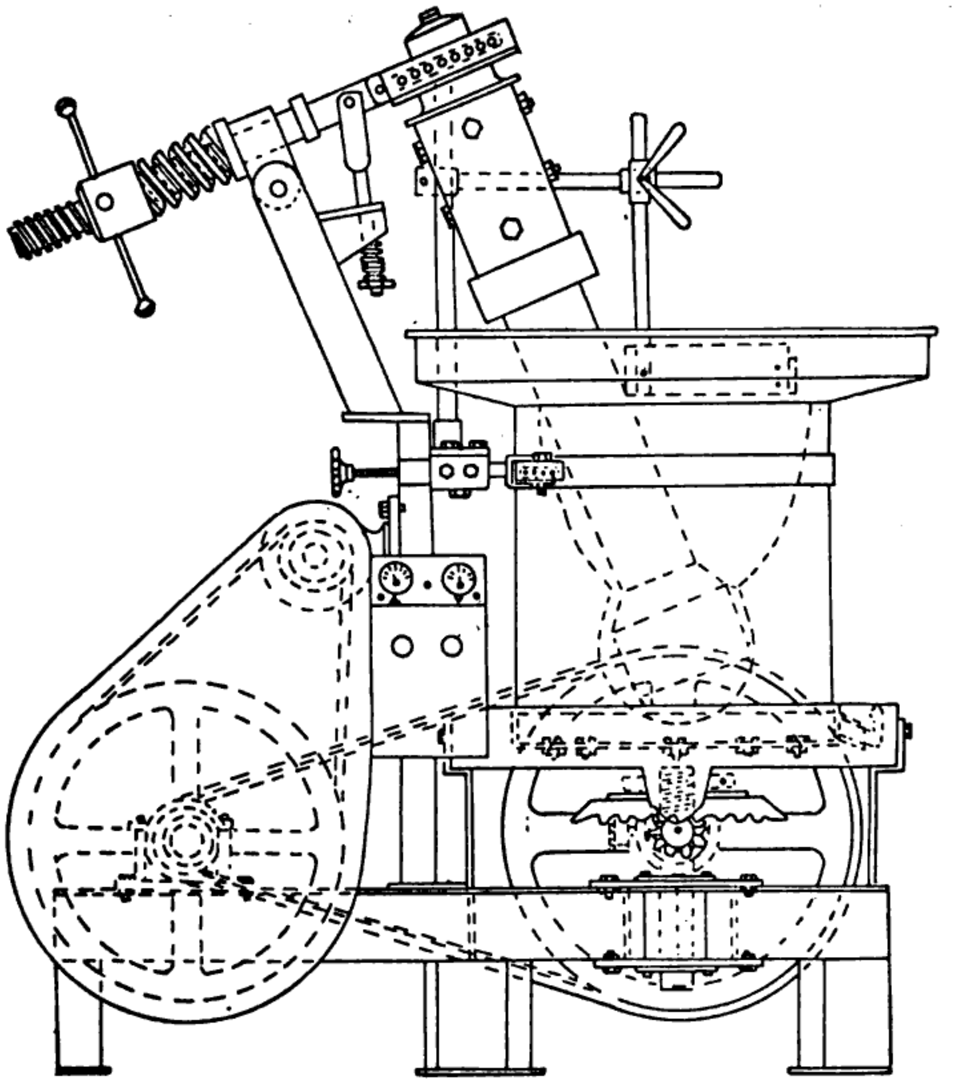

Fig. 23. Portable power ghani (Courtesy: Khadi and Village Industries Commission, Bombay)

few hours of receipt in wooden crates. Women had no difficulty operating the portable power ghani.

Table 12 shows comparative performance data for three kinds of ghanis: the portable, Wardha and overhead power types.[59] The portable unit had a greater crushing capacity, a shorter crushing time and a slightly lower cost of crushing than the other two. Yields of the two power units were the same, but higher than in the Wardha ghani. In another study in which 175 kg of safflower seeds were crushed both in an overhead power and a portable power unit,[62] the comparative figures were as follows: yield 76 and 81 kg, time 601 and 373 minutes, and power consumption 9.1 and 7.6 units. The compactness and convenience of the portable unit were its further assets. Some 4000 of these units were in operation in 1985, and 15 firms now manufacture them to KVIC designs. After-sales service and advice are provided.

Table 12. Comparison between performances of a bullock-driven Wardha ghani, an overhead power ghani and a portable power ghani[a]

	Wardha bullock-driven ghani	Overhead power driven ghani	Portable power ghani
Capacity per charge, kg	6 to 10	12 to 15	12 to 15
Crushing capacity per working day of 8 hrs, kg			
a) For sesame or groundnut	60 to 80	100	115
b) For mustard	40 to 60	60 to 80	60 to 80
Crushing time per charge, mts			
a) For sesame or groundnut	90	60	50
b) For mustard	150	90	75
Cost of motive power for sesame crushing, Rs			
a) Daily	10.00	5.50	6.00
b) Per quintal of seed	12.50	5.50	4.75
Floor space required, sq. m.	37.2	7.4	3.4
Yields of oil, %[b]			
Groundnut	45—49	40—47	40—47
Sesame	40—45	42—47	40—45
Copra	55—62	61—63	60—63
Mustard	30—35	31—37	25—33
Safflower (kernels)	45—49	50	48—50

[a]Ref. 59
[b]Not strictly comparable between different ghani types, since different lots of seed were crushed

Portable overhead power ghani: Certain drawbacks of the portable power ghani became apparent with its widespread use. The rotating drum consumed more energy than the rotating pestle. The shaft, roller bearings, ball bearings, flanges and rollers had all to be of extremely sturdy construction to withstand the load, and the drum had to be precision-turned. These were costly to achieve. Any repair required skills outside the range of an artisan, and expensive to hire. In another conceptual turn, the rotating pestle concept was reintroduced into the many good design features of the portable power unit. The new portable power ghani with an overhead drive (Plate 23) was in course of field-testing in 1985-86.

7.5 Processing Major Oilseeds in Ghanis

Eight major oilseeds are considered in this section. They are well-known materials that are processed in modern equipment in many parts of the world, including India. Such processing is fully described elsewhere, and for the purpose of the present book, only the processing of these oil-

seeds in ghanis will be described since this operation is practically unknown outside India. Even here such ghani processing is on the decline, and Chapter 12 will furnish information on the state of current technology for each oilseed in India.

SESAME

The sesame is India's oldest oilseed, and the one that has been longest subject to crushing in ghanis. Section 7.3 (p. 218) has an account of the crushing of 10kg of sesame seed in a ghani with periodic additions of water.

The sesame grows all over India, and there are some local variations in its mode of ghani crushing. In south India, in place of water, an aqueous solution of 5 to 10 per cent on the weight of seed of jaggery (uncrystallised brown sugar) is routinely added in lieu of water during the ghani operation. It is variously believed to raise the yield of oil through promoting cake binding, enhance the keeping quality of the oil and improve its flavour, and improve the compactness and palatability of the residual cake to animals.

That cake-binding is advantageous in ghani crushing of sesame seed seems to be borne out by practices elsewhere. The use of the bark of *Cassia auriculata*, the tanghedi tree, is noted by Watt a century ago,[51a] and again later the seed of the same species, called tarwar, is reported in use as a crushing additive.[36a] Stalks of the tamarind tree (*Tamarindus indica*) are also employed.[36a] After the oil has been crushed and drawn, no water is added to it, and the oil is simply left undisturbed to settle overnight before decanting.

In 1950, the yield of sesame from traditional ghani crushing was given as 38 per cent,[36a] and Table 9 (p. 215) shows the range of values. An increase of 1 to 2 per cent over this, and a 10 to 20 minutes saving of crushing time, was claimed in 1970 through minimal water addition and increased compacting of cake.[48] Initially, water is added in the usual way, and the ghani operated for five to 15 minutes. The oil drain is opened to permit oil and sediment to pass out, after which the oil is decanted from the sediment. The operation is next resumed, and after the cake has become 2 to 3 cm thick, the second lot of water is added totally into the pit, and crushing resumed. Just before the third addition of water (again directly into the pit and effected when the cake is about three-quarters pulverised), the sediment separated from the initial run-off is put back into the chest. When operation is resumed, in about eight to 10 minutes the cake hardens and oil expelling occurs smoothly. Other oilseeds like rape-mustard, linseed, castor and groundnut are also stated to benefit from such a sequence during ghani operation.[43]

Sesame seed is generally crushed whole. In the coastal areas of Krishna, Guntur and Visakhapatnam in Andhra Pradesh, a tradition existed of crushing the seeds after they had been dehusked by first steeping the seeds, held in closely-woven wicker baskets, in water, then dehusking them by agitation or trampling, and finally washing the light skins away in running water.[63]

The oil derived from such kernels had a light colour and mild flavour which was prized. Dehusked sesame seeds were also preferred for making scented oils (page 163).

Ghani sesame oils fetched a premium price of 3 to 5 per cent over the factory-produced product when both were available in the forties.[63] Its consumer virtues, a result of gentle processing, were stated to reside in a mild, non-burnt odour, a 'sweet' flavour, and a light colour "free from an orange tinge".[63] The keeping quality of ghani oil was also rated to be high; cold-drawn sesame oil was stated to have a shelf life of four months, against half this for mill oil.[63] However this is open to doubt, since ghani oils frequently have a high moisture content, especially if drawn before the froth has subsided,[43,45d] and such oil "is of the worst possible quality",[10a] developing free fatty acidity with ease on storage. Keeping overnight is stated to reduce the moisture level to half the specified limit of 0.25 per cent,[108] and settling with 0.5 per cent of common salt improves keeping quality.[45c] Adding 0.1 per cent of sodium bicarbonate to the seed mass during ghani crushing also doubles the keeping quality of the resulting oil, as does the addition of 0.01 per cent propyl gallate to normal ghani oil.[45c]

About a century ago, all sesame oil was ghani-pressed. By 1956 this had declined to 83 per cent;[42b] thereafter there was a steep decline, and in 1983-84, just 12 per cent of sesame seed was being crushed in ghanis[65] (see Chapter 12).

Rape-mustard

In the ghani crushing of rape-mustard seeds, rather more water (900 ml against 750 ml for sesame) is added. This is perhaps because, apart from achieving oil expulsion, water in this seed also brings about the hydrolysis of various glucosinolates present, through the agency of the enzyme myrosinase, which is also present, and aided by the prevailing warmth. Slow grinding and frictional heat development release a maximum of pungent isothiocyanates which enter the oil to give it a sharp taste and pungent flavour that is greatly relished along the Indo-Gangetic plain. Mixtures of seeds of *Brassica juncea* (rai, say about 70 per cent), *B. campestris* var. *sarson* (sarson, about 15 per cent) and *B. campestris* var. *toria* (toria, about 15 per cent) are crushed to achieve the three desiderata of high oil yield, sharp taste and pungent flavour. Traditionally, ghanis and pestles made of wood were used, since contact with metal was believed to ruin the flavour. Even the metal rotaries and pestles now employed for crushing these seeds in factories are clad in wood for this reason. In traditional crushing in the small ghanis that are used, with say a 5 kg seed charge, some 450 ml of water is added.[42e] About three-quarters of the seed is put in the pit, some 90 ml of water poured round the chest, and the operation is started. After about 25 minutes, the powder in the chest will appear dry to the touch and oil begins to appear. The rest of the seed is now evenly pushed in, and another 135 ml of water is added to the chest

and 90 ml to the pit. After a further 15 to 30 to minutes of working, the third large addition of water, from 225 to 325 ml depending on the estimated state of the cake, is added entirely into the pit and crushing recommenced. A few minutes before crushing is complete, about 100 ml of water is sprinkled evenly on the cake in the chest, and the operation rapidly brought to a halt.[42e]

It is not usual to add any extraneous material during crushing of rape-mustard seeds, but some are on record: in Punjab grass and linseed stalks, and in Sind (now in Pakistan) stalks of bajra (*Pennisetum typhoideum*) and jowar (*Sorghum vulgare*), and sometimes salt and coriander.[41] A byproduct of the soap industry called gadd (perhaps spent lye) was claimed to increase oil yield by 1 per cent.[41] Addition of warm oil from a previous run to hasten extraction is practised.

Today only some 5 per cent of all the rape-mustard seed that is processed is dealt with in traditional ghanis. Another 90 per cent of the seeds are crushed in oil mills using batteries of rotary units that simulate ghanis, and the rotary cake so obtained is run through an expeller to yield about 2 per cent more oil which is added to the pungent rotary oil.

Apart from great demand as a cooking and pickling oil, mustard oil (as it is commonly called in India) is also used for dressing the hair and for body massage. For the latter purpose, the pungent oil of *Eruca sativa* or jambha, a related species, was stated to be preferred at one time in Sind when pressed from fresh seed; if the seeds were old, the oil pressed from them was considered 'sweet' and used only for edible purposes.[41]

COPRA

Copra is an extremely fibrous material, and only 300 ml of water (compared to the 750 ml employed for sesame oil) is needed to ghani-crush 10 kg.[10e] Of this water, some 60 ml is added at the start, all at the top. After disintegration for 10 minutes, the material is raked with a crowbar, and another 120 ml is added in the chest and 60 ml in the pit. After a further 10 minutes of rotation, the third lot of 120 ml of water is put into the chest. Oil extraction is easily effected, and on standing overnight the clear oil is decanted. Sometimes 50 to 125g of gum acacia is added during crushing.[38]

Copra from sun-dried, fully mature nuts is preferred for crushing over smoke-dried material.[51b] For the most delicate flavour however, such as is preferred in the coconut oil that is employed to dress the hair or in medicine, fresh grated coconut meat is boiled with water to give what is called venthenna[10b] or avel,[51b] which is preferred to the muthel similarly derived from copra gratings.

Coconut oil was traditionally derived at a domestic level by boiling, and for commercial purposes in chekkus. The latter has been almost totally replaced by crushing in metal rotaries using heavy solid metal pestles, and to a lesser extent in modern expellers (Section 12.5). Such oils today make up 98 per cent of all the coconut oil produced.

LINSEED

The yield of ghani oil from linseed is placed in the range 25 to 30 per cent, usually 28 per cent.[49] Ghani crushing follows much the same water-addition sequence as earlier described for sesame seed, and the same quantity of 750 ml of water for every 10 kg of seed is used. All the seeds are added at the start and water is added even before the animal starts its circumambulation so as to provide a grip on these slippery seeds. If sufficient water has been added for good cake formation, the oil initially squeezed out will rise again from the pit into the socket. If this does not happen, the drain is opened, and the sediment that comes out is put back with the cake. Turning over with a crowbar during the run is not necessary with linseed cake, this being done only at the very end. When the oil is seen to be clear of suspended matter, the operation is stopped and the pestle lifted out. Brushing the final cake layer with water using the palm of the hand, as done for sesame, is not necessary with linseed.

At one time, linseed oil was used for edible purposes to a considerable extent in central India in the region round Nagpur. Such edible oil with an uncooked flavour was always expressed in wooden ghanis, and the oil from metal rotaries was relegated to industrial use.[52,152f'] Ghani linseed oil is now rare, and rotaries and expellers have taken over crushing.

CASTOR

Being a viscous oil, expulsion of castor oil in a ghani calls for special treatment. Seed cooking is one of these, and the first step is to put the seeds in a wicker basket or a metal vessel with a perforated bottom. This is then either dipped in boiling water, or hot water is poured over the seeds for a few minutes till they are soft.[42e] Sometimes the wicker basket of seeds may be placed for steaming over a metal dish of boiling water. The seeds are then shaken free of water and fed to the ghani. No extra water is added at all, as with all other oilseeds. After about 15 minutes oil begins to appear, and the mass is raked over once or twice, and the drain opened. If the seeds are too wet, the cake will form a sticky mass which pushes the pestle up. If this happens, a flaming torch can be passed over the surface of the material in the ghani to warm up the cake and evaporate water, after which crushing of oil is resumed.

At the turn of the century, Watt described a castor crushing operation.[51b] Some 15 kg of castor seeds were pounded with a stone to achieve decortication, and the 12 kg of kernels which resulted were treated with one kg of boiling water, and then crushed in a ghani with a plugged outlet, when, in 15 minutes, half a kilogram of oil collected. This oil was drained out, heated, and put back repeatedly till exhaustion, a 35 per cent yield of oil being obtained. The final oil was boiled for clarification from impurities.

Water added during steaming and pressing is believed not to mix with the oil, but to be retained wholly in the cake. However the powdery suspension that stays with the oil is known to carry water, and to lead to

early rancidity of the oil if not removed. Sometimes 1 per cent of salt is added to the cloudy oil, which is stood overnight and filtered through jute cloth. Exposure of castor oil to the sun was sometimes employed for both bleaching and precipitation of solids.[12c]

Cold ghani crushing of castor seed was used to give a very light-coloured oil for medicinal use.[10f] This was used both externally, for inflammation of the eyes and keeping the head cool, and internally as a purgative.[51c] Use of castor oil as a lubricant on cartwheels, and even for railway engines in their early years, was once widespread.

Today ghani crushing of castor seed has practically vanished. In fact even in 1956, when fair proportions of several other seeds were still being so crushed,[42b] castor seed had already moved to expeller processing (Section 12.5).

NIGER

In a chekku in Mysore city which crushed niger seed, the mortar, its lining and the load-beam were all made of sirish wood (*Albizzia lebbeck*), but the stout pestle was of babul (*Acacia arabica*). The seeds were black and shiny, like little wires, and addition of water right at the start to provide grip was stated to be important. The crushing operation resembled that for sesame, except that no additive in the water such as jaggery (uncrystallised brown sugar) was used. The oil yield was about 28 per cent.

In the past, niger seed was mixed with other oilseeds before crushing. This may have been done to fetch better prices for an unfamiliar oil and cake, but it was an acceptable practice. A board hung outside a shop even in 1952 proclaimed the selling there of mixed oils (Fig. 24). This would today invite prosecution for adulteration. A niger marketing report of 1952 states that "telis invariably crush niger seeds with small quantities of edible oilseeds, such as groundnuts, safflower and sesame"[63] and again elsewhere

Fig. 24. A board of the 1950s placed outside a shop reads: "Mixed oils sold here" in Hindi and Urdu (Source: Linseed Marketing Report[52])

that, in Hyderabad state, "niger seed oil and cake production. . . are therefore only available in a mixed form."[63]

Ghani processing of niger seed appears to have given way almost entirely to treatment in expellers.

SAFFLOWER

The one oilseed still crushed fairly extensively in ghanis today is the safflower, about half the seed production being so routed. Also, an elaborate traditional system of decortication has been developed for this oilseed, and only pure kernels are fed to the ghani.

The seed is first ground between two heavy circular stone which rest on each other, a very ancient device that goes back to the Indus Valley civilisation of 4000 years ago. In improved versions, the upper stone carries a central metal strip mounted diametrically across the central hole. The strip rests on a peg fixed at the centre of the lower stone which rises through the upper hole, and serves to lift the former slightly off the base stone to provide an annular space. Ball bearings facilitate easy rotation by hand. The ground material falling off the outer edge is a mixture of hulls and kernels, which is sieved in a suspended cradle with a replaceable sieved bottom (Plate 22). By changing the latter three times, most hulls could be left behind and essentially kernel material collected. This was then winnowed in the draft created using a large rectangular piece of cloth, pegged at two corners and flapped at the other end, to give almost pure ground kernels in 80 per cent yield.

These kernels are now crushed in a ghani made of neem wood, stated to be about a century old. The inner sleeve made of babul wood was changed every four months, using larger pestles as the pit became enlarged with use. The lower half of the pestle had long metal strips fixed along its length with rivets. The sequence of water addition (no jaggery was used) was as in sesame crushing. The oil was stood for clarification overnight, sometimes after adding cold water. Once-pressed oil may be heated and poured over the cake built up in the ghani, followed by brief rotation. This hastens the crushing and yields a clearer oil. Heating the pressed oil, which carries a lot of sediment (danka), can result in a charred smell which will pass into the entire lot.[45a] The yield of safflower oil is stated to be 44 per cent on the weight of kernels.

In recent times, even when ghani crushing is employed, these operations have been modernised. A traditional surpa or morram (hand winnower) is still employed to clean the safflower seeds of trash. The cleaned seeds are ground in a horizontal or vertical stone grinder with one fixed and one stationary wheel, and the ground material is discharged through a chute into a series of graded sieves mounted as a battery in two rows. Through a vibrating motion the hulls are sieved away to different extents to give a series of emerging materials. These are fed into the stream of an automatic blower, which throws the components present in the mix to different

distances, giving two heaps. The pure kernels are then soaked overnight in water and crushed in a ghani, usually a motorised model.

The oil collected from several runs by draining was warmed over a fire. It was then poured over the last spent cake in the ghani, and left overnight to emerge as a fairly clear oil which was stored overnight and decanted. The accumulated debris was put back into the ghani during a subsequent operation. A 25 per cent oil yield on seed basis was obtained.

Even now, about half the safflower seed produced is still expelled in ghani operations, yielding 39 per cent of all the safflower oil produced (Section 12.5). The other half on modern expelling gives another 57 per cent, and the remaining 4 per cent is oil that is solvent-extracted from expeller cake.

Groundnut

When groundnut production spurted in India after about 1850 (see Section 3.2, page 69), the nuts were naturally processed by the prevailing ghani technology. Crushing groundnuts in their pods was considered preferable to crushing kernels, and was also easier on the animal. The percentage of oil extracted was reported not to be lowered (this is doubtful), and the labour of decortication was saved. Only the capacity per charge was recognised as being reduced.[42a] The seeds were heated in an iron pan before crushing, failing which the extract looked milky and was full of sediment.[42a] About 700 ml of water was added for a 10 kg charge, in the same sequence as for sesame seed crushing. Hot water was added to the expelled oil followed by standing overnight and decanting.

By 1941, it was common to crush only groundnut kernels, but sometimes nuts in shell, or mixtures of these with kernels, were used.[39a] Mixed crushing was also in vogue in 1941,[39a] especially in Bombay and Hyderabad rather than in Madras. Niger seeds and groundnuts mixed in equal proportions were crushed in a village in the Pune district. In Belgaum, safflower seed, groundnuts and sesame seed in a 7:3:1 mixture were noted as being crushed, and in Hyderabad, mixtures of groundnuts and safflower seeds. Ghani yields from groundnuts were 35 to 37 per cent of oil.

When the next big spurt in groundnut cultivation occurred between 1920 and 1930, modern expellers had appeared and were an alternative to traditional ghanis. In 1935-36, in Madras state, 73 per cent of the groundnut production of 475,000 tonnes was crushed in chekkus.[39b] Of Bombay's 335,000 tonnes however, only 17 per cent was ghani-crushed, in Hyderabad state (125,000 tonnes) about 25 per cent, and in the Bombay and Kathiawar states (also 125,000 tonnes) only 4 to 5 per cent. Overall, some 45 per cent of all groundnuts would seem to have been processed in ghanis in 1935-36.

By 1949-50, this figure was estimated to stand at 32 per cent,[64] and in 1955-56 at 20 per cent,[42b] reflecting increasing processing by modern machinery. Alongside, the production of groundnuts was also rising rapidly. By 1983-84 just 2.5 per cent of groundnut oil production was

estimated to have been derived from traditional as well as improved, power-driven ghanis.[65] The actual figure was 125,000 tonnes out of a groundnut kernel production of 5.1 million tonnes (equivalent to 7.3 million tonnes of nuts-in-shell). Expeller oil constituted 95 per cent of the total, and solvent-extracted oil the remaining 2.5 per cent (see Section 12.5).

Any traditional preference for ghani groundnut oil, such as that expressed in 1941 for the oil produced in stone ghanis in Virudhunagar, Tamil Nadu, which fetched a premium price, appears to have receded into history. The lower oxidative stability of ghani over expeller groundnut oil may be a factor overriding considerations of flavour, taste or colour (see Section 7.5, p. 231).

CHAPTER 8

Other Small-scale Processing Methods

8.1 Winning Oils from Oilseeds

Despite its apparent simplicity, the ghani is a fairly sophisticated device, built and run by hereditary professionals, worked by specially-trained animals, and operated for community purposes. For small domestic needs, and especially in remote areas, for example where tribals dwell, easier techniques involving simple principles arose. These will be outlined in this section.

Another activity was more recent, and was again spearheaded by the Khadi and Village Industries Commission (KVIC). This was the development of non-ghani mechanical presses, like a hand screw-press and a hydraulic press, which could serve the village artisan, but did not need the use of animal power. These were smaller in scale than the ghani, and in the event were found to yield oil even from materials that were pressed in a ghani only with difficulty, or not at all.

Water Boiling

Several oilseeds which carry viscous or high-melting fats can be rendered by grinding and then boiling with water.

Castor: About a century ago, it was not uncommon to process castor seeds with water.[51c] Several variations of procedure are on record. In one, castor seeds were first roasted, then pounded in a mortar and finally boiled in four volumes of water with constant stirring to release oil to the surface. In another, castor seeds were first treated with hot water or steam, then dried for two or three days, pounded in a mortar and finally freed of oil by boiling with water. Alternatively the seeds were soaked overnight, ground using a ghani, and then squeezed out in a cloth to release oil. Yet another variation was to first roast the seeds, then grind them in a stone edge-runner drawn in a circular trench by bullocks (a device commonly used for crushing lime in India), and finally boil them with water. The mangling of castor seeds could also be achieved in the corrugated metal rollers used to crush sugar cane, and the pulp then boiled with water, or even cold-pressed in a ghani, to yield a medicinal grade of oil. The wet

oil obtained by aqueous rendering was freed of moisture and other impurities by heating, settling and decanting.

Coconut: Release of coconut oil from the gratings of either fresh coconut or copra by boiling with water was, and still is, a common domestic procedure.[106,51b] The traditional coconut scraper, a curved and serrated iron blade fixed upright on a wooden base, was used to prepare the gratings. These were then boiled with a minimum of water, since a larger volume was believed to lower oil quality. The term avel was used in the Thana district of Bombay a century ago for the oil from fresh coconut, and muthel for that from copra.[106] The former, with its delicate flavour, was employed as a hair dressing, for which use coconut oil is very popular even at present. Coconut oil from sun-dried copra, untainted with smoke, was the choice for cooking purposes.

Mahua: Boiling or steaming, grinding and rendering with water is a process sometimes used to render fat from mahua kernels.

Sal: The tribals of Orissa first burn sal fruit to destroy the sepals, then decorticate the seed by rolling under a plank, and finally boil the kernels with water. The latter are then dried, ground and boiled with water to release the fat, which on cooling forms a crust on the surface.

Dhupa: As soon as it falls after the start of the monsoon season, the fruit is depulped on the spot with a knife and then decorticated with stones. It is known that dhupa fat cannot be extracted in a ghani, which is used only as a grinding aid in the village.[165] The kernel pieces are first cooked with water for two to three hours till they have softened, and placed in a ghani pit. The pestle is inserted and then rotated by two men standing on either side of it and passing the pestle from one to the other. The ground paste is placed in water in a vessel and boiled with occasional stirring for four to six hours. When the fat and hot water are poured into another vessel and cooled overnight, the fat sets as a hard layer. It may be boiled again with water once or twice to clean it up. On cooling, dhupa fat yields solid grains in a liquid base, thus strongly resembling Indian ghee.

Such rendering by boiling with water gave poor yields.[152b,166] In an actual trial, 909 kg of dhupa kernels yielded just 18 kg of fat which still carried 25 per cent water, a yield of well below 2 pet cent.[167] When iron vessels were used for boiling, the kernels turned violet or dark brown, and the water extract when dumped was found to destroy grass and plant life, perhaps through the presence of phenolics.

Roasting

Strong dry heat can rupture cell walls and cause oil to flow, but the oil could be heat damaged. This principle has been used traditionally with safflower seed. A round earthen pot is buried in the ground, a perforated cover placed on it, and a second pot carrying safflower seeds placed inverted on the cover.[10c] Alternatively an upper pot with a perforated bottom carrying seeds may be placed over the opening of the buried pot.[51d,66] Fuel is piled on the ground around and against the upper pot to roast the

seeds. An oil begins to flow out which collects in the bottom pot, and the yield is stated to be about a quarter more than is obtained in a ghani.[66] The oil is not ordinary safflower oil but a heat-bodied product called roghan which has long been used in dressing and preserving leather, and for making a form of decorative cloth (see page 170).

Incidentally, a similar roasting technique is employed to obtain from the woody nuts of the cashew (*Anacardium occidentale*) and the bhilawan (*Semecarpus anacardium*) dark phenolic liquids[67] that are highly valued as polymerisable materials yielding hard and glossy surface coatings.

Wooden Presses

Only next in rank to the ghani as a means of obtaining oil, though restricted in use essentially to the tribals of Madhya Pradesh, Bihar and Bengal, are wooden presses. Plank presses are termed chappa, and tree presses tirahi or tirimo.[68] Both appear to be used essentially for crushing mahua seed.

The chappa (Fig. 25) consists of two wooden planks in which receptacles with a drain groove may be scooped out to hold mahua kernels that have first been ground, placed in packets of plaited reeds or mats, and then boiled or steamed.[67] Pressure in the horizontal chappa can be exerted using a torniquet and, when the planks are vertically set, either with a torniquet or a movable stake set in the ground.[69]

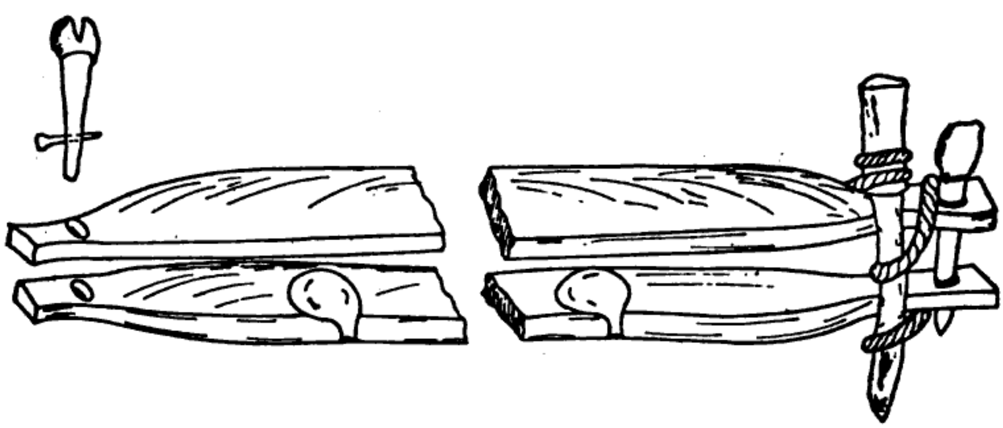

Fig. 25. Horizontal plank press or chappa (Courtesy: Khadi and Village Industries Commission, Bombay)

In the tirahi or tirimo, an upright tree serves as the stationary fulcrum, and another tree trunk is lodged in a hole in the first tree to serve as a pressing lever (Fig. 26). Steamed mahua kernels in packets may be rested on a H-shaped upright or simply on a large stone. Sometimes the pliable fork of a tree may itself serve to exert pressure.

At Baran in Rajasthan, the Non-Edible Oils and Soap Industry division of the KVIC attempted to upgrade the chappa by the use of screws and a lever to exert pressure,[71a] improved steam cooking of the mahua kernels, and insertion of an iron plate in the packet before crushing.[70] The possi-

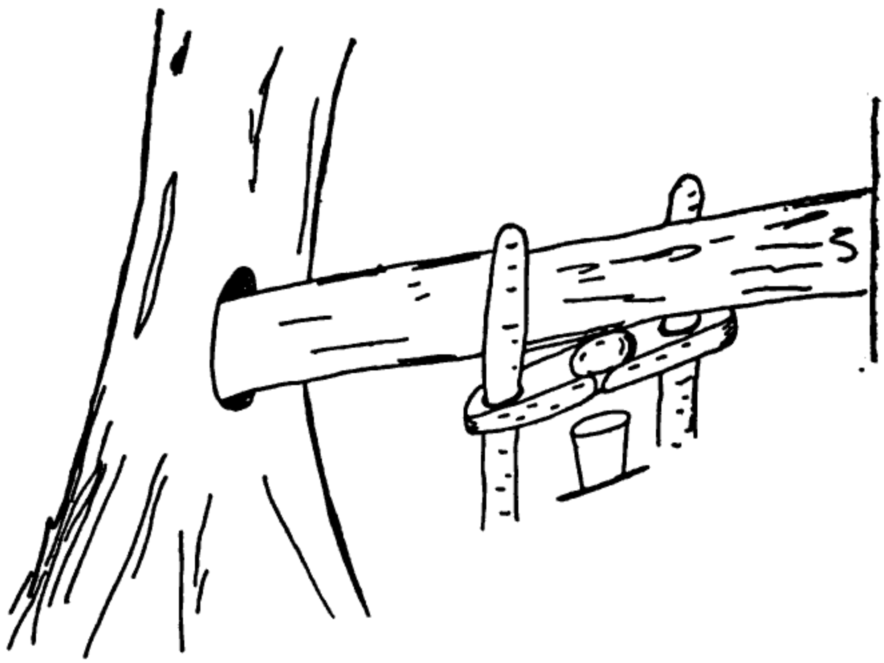

Fig. 26. A tree press or tirahi (Source: N.K. Bose[69])

bilities of the chappa were endorsed in April 1959 during the Regional Seminar held under KVIC auspices in Bankura in West Bengal,[72] but no further development is recorded.

SCREW-PRESSES

The horizontal screw-press: About a century ago, the hand-screw press worked by human labour using either the hands or the feet, was introduced for crushing linseed from Europe into India.[10b] In 1908 it is described for the crushing of groundnuts in South India, [39a,73] and later for castor seed.[74] This press was displaced in turn by rotaries, hydraulic presses, expellers and solvent-extraction units.

In 1958, use of bullock power to work a horizontal screw-press was described.[71b] Ten charges, each of 56 kg, could be crushed in 12 hours, leaving 9 to 10 per cent of oil in the cake for most oilseeds, and 6 to 7 per cent for castor. The arrangement was stated to be well-suited to crush mahua kernels all the year round.

Other KVIC trials with the hand screw-press were reported.[75,76] Mahua kernels were powdered in a foot-pounder (p. 80), tied in a gunny bag and cooked for a few minutes in a steaming vessel. Packets holding about 1 kg were placed between the plates, and pressure applied by two men. A second pressing was made after breaking up the first cake into pieces, re-cooking and mounting. In eight hours, from 130 kg of mahua kernels, the oil yields were stated to be "better than in ghanis".[75] Hard seeds like neem and pilu,[75] and dhupa,[76] which are only crushed with difficulty in a ghani, could be processed.

Vertical screw-press: As the KVIC put it, the vertical screw-press of 1963, with a capacity of 100 to 300 kg in eight hours, was for "use on a decentralised basis".[77] A seed disintegrator and a steaming vessel were essential auxiliaries. After use, design improvements were effected and a better disintegrator came out in 1965.[78] In Pune, 53 vertical hand screw-presses and 50 disintegrators were manufactured to approved standards, and 16 were sent for trial to places where a substantial quantity of non-traditional oilseeds had been collected.

Full constructional details and drawings were furnished by KVIC in its 1966 bulletin, "A guide to an economic cottage-scale oil extraction unit".[78] This unit would accept 6 kg of ground seed per charge, but since pressing time was so short, the press could deal with 144 kg in eight hours. Working of the press was described in a KVIC handbook of 1968.[79] Cooked meal held in hessian packets were alternated with metal discs in the perforated metallic cylinder (Fig. 27). A screw piston working in the perforated cylinder cage provided pressure, which was developed through

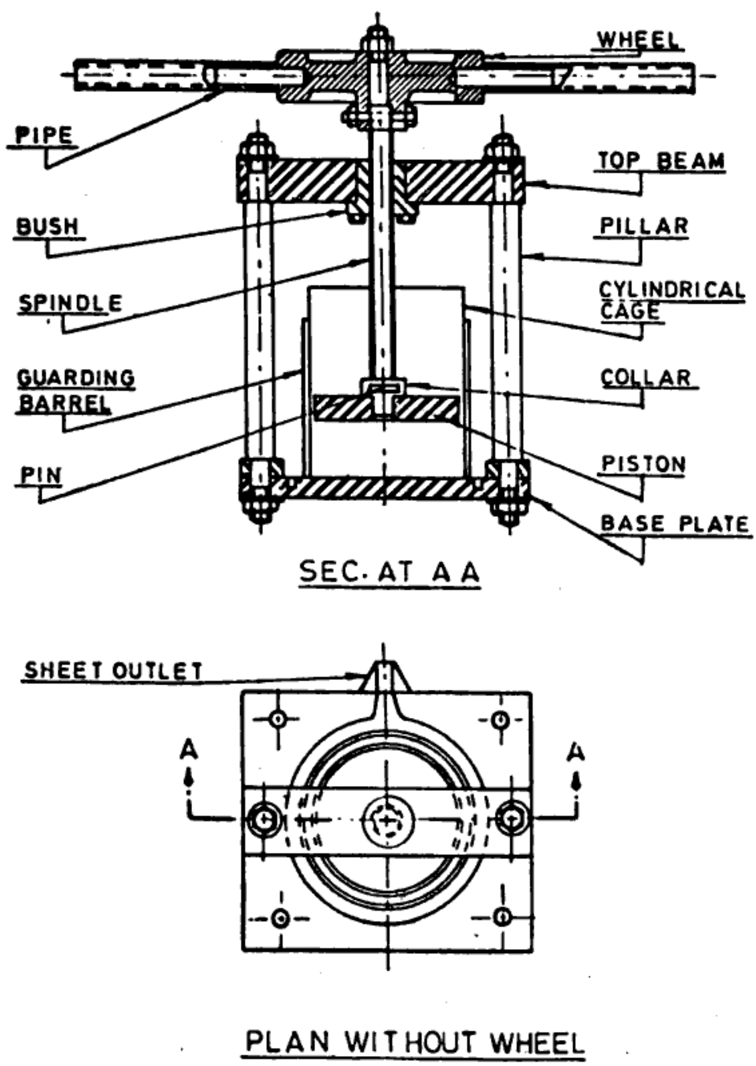

Fig. 27. Vertical handscrew press (Source: Khadi and Village Industries Commission, Bombay[78])

a long handle pressed down from the top. The auxiliary disintegrator had a hopper on top for feeding seed between two corrugated rollers driven at different speeds through a series of adjustable gear wheels. The steaming box was rectangular and could be placed above a brick hearth. Water was placed at the bottom to yield steam, and three perforated trays placed above held the ground material in the tightly-closed box. About 15 minutes of steaming was recommended, and the first-press cake was to be broken up in the disintegrator without delay and steamed again before a second pressing.

The unit was evaluated for extraction of sesame seed, linseed and groundnut kernels in 1969.[80] It was found essential to wrap the cooked materials in hessian without delay and crush also at once, applying pressure gradually at first, and then building it up. The first cake very quickly set hard, and had again to be disintegrated, as soon as removed, for repressing. For sesame seed and linseed, satisfactory oil yields of 45.0 and 35.6 per cent were recorded. For groundnut kernels, where ghani oil yields are 45.5 per cent, the yield of 38.2 per cent in the hand screw-press was poor. A combination procedure raised this to 46.2 per cent, consisting of a first extraction of groundnut kernels, after 10 to 12 minutes steaming, in a hand screw-press, followed by breaking up the cake by hand and pressing again in a ghani. For safflower kernels also the yield of oil, which in a Wardha ghani is 36 to 37 per cent, was only 25 per cent even after double crushing in a hand screw-press. However the unit had many virtues, like low cost, simplicity of use, versatility, the absence of animals, and above all a very much higher oil output per day.

Three non-traditional oilseeds were also crushed for evaluation on a hand screw-press.[81] From neem seed, two pressings, after cooking each time with direct steam, yielded only 26.3 per cent oil, which was not an economic yield. A first screw-pressing, followed by ghani treatment, yielded from 5 to 6 per cent more oil. Mahua kernels, on disintegration and steaming twice successively, yielded 37.6 per cent oil, which is 81.9 per cent of that present and therefore satisfactory. Pisa seeds were decorticated, and the kernels (60 per cent yield) pulverised, steamed and screw-pressed. First oil yields varied rather widely from 42 to 61 per cent averaging 51.2 per cent. Sun-drying the first cake, cooking and pressing a second and then a third time gave a total 57.5 per cent yield of oil, constituting 82.5 per cent of that present.[81]

In another study,[50] when rubber seed kernels were first powdered fine (70 per cent passing 16 mesh), the press became choked. However, if the kernels were first crushed, and the cake powdered thereafter, oil yields were 5.5 per cent higher. However even this yield was about 2 per cent below that obtained at 60°C in a water-jacketted metal ghani (page 220).

Clearly the protocol for each oilseed required to be crushed in a hand screw-press would need to be individually determined, and the trials described above must not be considered the final word.

HYDRAULIC PRESS

Commercial hydraulic press: This was well-established in America by the start of the present century for crushing linseed and cottonseed.[81A] The flaked, cooked seed was first compressed in moulds into flat cakes which were then placed in press cloths of woven camel or sheep wool.[81B] The latter were then subject to hydraulic pressure either in an open box press or closed cage press, mounted singly or in batteries.

In India, an 1893 report mentions the 'recent installation' of an "English steam press" to crush 375 kg of linseed a day.[10d] This could have been either a horizontal screw-press driven by steam power (raised by burning wood), or a hydraulic press using steam in place of electric power to work the hydraulic pumps. By 1921, a number of mills in Bombay had "fairly modern hydraulic machinery with daily outputs varying from 2 to 50 tons of seed per day."[81c] In 1926, even the United Provinces alone had 26 hydraulic presses of the Anglo-American make,[81D] and use of hydraulic presses in the Punjab was being strongly urged in a 1923 report.[81B]

Hand hydraulic press: In adopting the hydraulic pressure principle, the KVIC employed only hand power to facilitate use of the unit by village industry. In November 1968, an experimental model was demonstrated at the First Saranjam Sammelan held in Rajkot.[82] Hydraulic fluid was pumped by a jack to slowly raise its rim till the maximum pressure of 50 tonnes was attained. Fixed to this rim and moving up along two support pillars on either side was a square plate with raised edges into which flowed the oil. An iron block, whose height could be adjusted, was positioned with screws on the iron pillars. This block carried a cylinder of cast iron moving closely within the perforated block, in which the cooked meal was placed in packets separated by cylindrical flat iron plates. If the maximum pressure possible had not been attained when the rim had risen to the top, cylindrical blocks of wood of suitable thickness could be inserted into the gap above the cage.

The KVIC hydraulic press was evaluated for removal of oil from decorticated rubber seed.[83] Addition of known quantities of moisture, followed by cooking using indirect heat, was found far superior to direct steaming of the material, the oil yield after two pressings in each case being 44 and 28 per cent respectively. Since the optimum moisture content was the natural seed moisture level of 8 to 10 per cent, simple indirect steam-heating was all that was required for the first pressing, with 3 per cent of additional moisture being required for the second. The high yield of oil did include some 1 to 1.2 per cent of sediment, which was easily reduced to a 0.13 per cent level by passage through a rotating basket centrifuge.

On a laboratory hydraulic press of the well-known Carver type, optimum conditions for pressing ricebran were found to be: moisture 7 to 12 per cent, temperature 100°C and time of pressing 60 minutes.[84] Varying the pressure from 5 to 35 kg/sq cm had little effect on oil yield, which was

7 to 10 per cent from batches of bran that carried 17 to 19 per cent oil, and 26.9 to 27.4 per cent from brans with 26.9 to 27.4 per cent oil.

8.2 Auxiliary Processing Devices and Techniques

Traditional methods of processing conventional oilseeds in ghanis and by other devices have been described in Sections 7.1 and 7.5. Processing techniques for non-conventional oils will follow in Chapter 9.

Since the turn of the century, and more particularly since the advent of Indian Independence in 1947, aids to the processing of all types of oils have been developed by research efforts. These have been at several levels. Nearly 50 years ago, mechanical devices for decorticating groundnuts-in-shell were widely in use in south India, and siever-shaker units for cleaning seeds like linseed and sesame were also in commercial use. The newer devices and techniques were mainly directed at the small operator who has limited access to capital. Two organisations were particularly active in this area. The Oil Technological Research Institute (OTRI) at Anantapur, in the state of Andhra Pradesh, had in mind the small entrepreneur, and worked on a very wide range of both conventional and new oilseeds; the descriptions below, when not referenced, are drawn from the volume of machinery profiles issued by the Institute.[85] The Khadi and Village Industries Commission (KVIC), with its Jamnalal Bajaj Central Research Institute (JBCRI) at Wardha, was particularly interested in unconventional oilseeds like neem, mahua and rubber seed, but also in those conventional oilseeds like safflower and groundnut which were still within the orbit of the ghani. The Central Food Technological Research Institute (CFTRI), Mysore and the Harcourt Butler Technological Institute (HBTI), Kanpur also contributed to the design of auxiliary oilseed processing equipment.

The processing units devised, with sometimes an innovation in operating technique, are conveniently described with reference to specific oilseeds, even though a few are of general application. The processing details, and results for unconventional oils, will follow in Chapter 9.

DESEEDING

The large seedheads of the oil-bearing sunflower are packed with seeds mounted in a fibrous base. A continuous thresher (OTRI) for removing the seeds consists of an endless moving belt made of rough coconut coir mat or mild-steel wiremesh moving over three rollers, the tension being varied by adjusting the central roller. The other belt, one end anchored and the other loose, lies stationary across the surface of the lower moving belt, and weights can be placed on it to increase the degree of abrasion. A unit of length 110 cm and width 60 cm can deal with 200 kg of sunflower heads daily, yielding bold seed 35, spurious seed and chaff 15, and deseeded heads 50 per cent. Another mechanical thresher (OTRI) consists of a beater with horizontal channel grooves rotating in a semi-circular grate built up either of bars or upright flats arranged side by side. The grate spacing is suitably adjusted, and with a properly-dried head, a machine

with a capacity of 3 tonnes/day yielded seeds 46, chaff 24 and empty heads 30 per cent.

DRYING AND STABILISATION

General: A solar drier (OTRI) useful for all oilseeds consists of three main components. The flat plate collector is fixed over a wooden box frame with one side open, and is slanted at an angle equal to the latitude of its location so as to ensure that sunlight always falls vertically. The exhaust fan of low rpm is mounted separately, and draws hot air into a brick bin with a platform grill on which the oilseed is spread. An 8° to 9°C rise in temperature over the ambient was achieved. A tunnel drier (CFTRI) can accommodate four wheeled-in stands each stacked with numerous wire mesh trays on which to load the oilseed needing to be dried using electrical heating.[86a]

Coconut: Whole nuts, or more frequently cups, are traditionally mostly sun-dried, but smoke driers are also used when the weather is inclement, usually to finish a drying operation before milling.[45b,87] These have been described in Section 3.1, p. 58-59. Indirect hot air driers, also in use to complete copra drying prior to its processing, can be of the natural draft or forced draft type.[87] In the former, hot flue gases generated elsewhere are caused to flow over or through the copra by convection using an efficiently-dampered ventilator, and no smoke comes into contact with the material. A copra drier of small size using agricultural waste as fuel was developed in India in 1982.[88] Forced draft driers are generally of large capacity, say 20,000 whole nuts in 30 hours, and a powerful fan draws hot air from a heat exchanger into the base of a drying chamber for even distribution by baffles. Compact tubular heat exchangers which can employ agricultural wastes as fuel are popular in India. Air is drawn through them with a powerful fan, and copra placed in the drying chamber on wiremesh platforms can be dried from a 15 to a 6 per cent moisture content in two drying sessions of six hours each.[87] Solar driers for copra are very cost-effective when the climate is favourable. A unit of 250-nut capacity (Central Plantation Crops Research Institute, Trivandrum) achieved a temperature 10°C above the ambient, and cut drying time in half.[45b]

Sesame: Freshly-harvested or wet sesame seed can be dried in a conveyor trough drier (OTRI) consisting of a slowly-rotating (4 rpm) steam-jacketed screw-conveyor which reduces seed moisture from 19 to 10 per cent, or 14 to 7 per cent, and has a capacity of 1000 kg/day.

Groundnut: A hand-operated drum drier (OTRI) can dry freshly-harvested groundnut pods from a moisture level of 23 to one of 9 per cent in eight hours at 80°C. The drum of cast-iron sheet is rotated by hand over a wood or charcoal fire supported below in a perforated tray. The unit also heat-stabilises ricebran (90°C, 30 minutes) and dries mango stones from 42 to 15 per cent moisture in two hours. Also designed to dry groundnut pods is a continuous drum drier (OTRI) consisting essentially of a barrel open at both ends rotating within a closed shell into which is admitted live steam

generated in a boiler. Angles mounted inside the barrel force a zig-zag path on the moving pods as they are dried down to a 7 per cent moisture level in 18 hours at a 2 tonnes/day capacity. The unit can dry other grains as well.

Ricebran: At a bran moisture content of 2 to 3 per cent, the lipase present does not function, but destroying the lipase itself requires heating bran of 18 per cent moisture content for just a minute to 100° to 110°C.[86b,88A] Numerous driers-cum-stabilisers have been developed in India.[89] These are mostly on a small scale to suit the usual capacity at which rice is processed, and are mostly batch stabilisers. A hand-operated rotary drum stabiliser (OTRI) is the same unit just described as a drum drier for the groundnut. Another batch unit (Paddy Processing Research Centre, Tiruvarur) is a rotating hot-air unit with heat distributing strips mounted on the shaft which serve to transfer heat (105°C, 50 minutes) and also effect mixing at a low speed of 8 rpm.[90] Steam at 5 to 7 psi is used in small tilting driers and large rotary driers (CFTRI) to achieve 100° to 110°C during slow rotation of bran.[86b] Open and closed steam, paddle stirring and long residence time (45 minutes at 100°C) are features of a cylindrical stabiliser (OTRI) with full instrumentation.[89] In a screw-conveyor type of unit (Indian Institute of Technology, Kharagpur), the bran is first steamed, then dried in another screw conveyor heated internally with steam, and finally pelletised.

Screw conveyors are also used on continuous ricebran stabilisers. One design (OTRI) employs hot flue gases, engendered by burning agricultural wastes in a hearth placed below, to stabilise the bran at 80° to 100°C in 15 to 20 minutes.[87] Infra-red lamps are used as the heat source in another unit (G.B. Pant Agricultural University, Pantnagar) in which the meal is exposed at 110° to 115°C for 10 to 15 minutes on a continuously moving belt.[87]

Two fluidised-bed units have been developed. In one (Indian Institute of Technology, Kharagpur), the temperature can be raised to 200°C by burning liquid petroleum gas, and the stabilised bran separated in a cyclone separator. In a novel design (Bal et al.[91a]), specially-graded sand is mixed with the bran in the fluidising column, heated either by band heaters or steam: being dense, the sand remains in constant movement in the zone of heat transfer. At 120° to 150°C the bran traverses the turbulent hot sand belt in 30 to 70 seconds, and then gets carried beyond it by the hot air stream to be precipitated in a cyclone.

An integrated unit (Sisir Banarjee[91b]) provides for five minutes' exposure to open steam of the bran as it travels through three cylinders before being directly pelletised (Fig. 28); the pellets are then dried, and keep well on further storage for a month.

Dielectric heating for six to seven minutes resulted in excellent stabilisation.[92]

Chemical stabilisation of rice bran has been achieved in two ways. Mixing the bran with 2 per cent of sodium bisulphite (OTRI) arrested

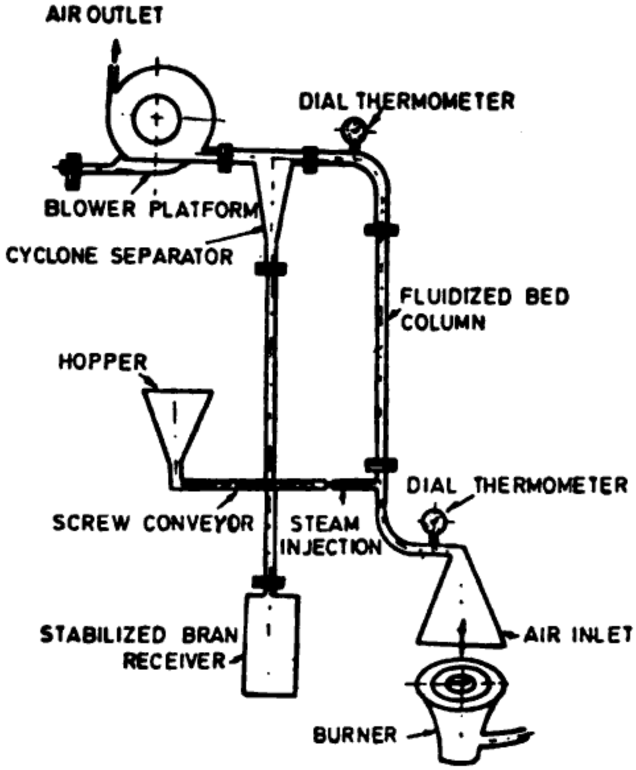

Fig. 28. Stabiliser-cum-pelletiser for ricebran (Source: Sisir Banarjee *et al.*[91b])

lipase action: acidity of the oil rose from 2.5 per cent initially to 3.5 per cent after a month's storage, against 24.0 per cent in the untreated material.[93] Thorough mixing even for a few minutes of concentrated hydrochloric acid (40 kg/tonne) with ricebran (CFTRI) resulted in a drop in pH from an initial value between 6.9 and 6.0 to a value of 4.0, with consequent bran stabilisation; the procedure appeared well-adapted to commercial use.[94]

Seed Cleaning

General: A small versatile seed-cleaning unit (OTRI) handling about 100 kg of material in two to three hours frees various seed of chaff and light trash, and can also size and grade them. The hopper feeds on to a detachable chaff screen of appropriate mesh. A powerful fan mounted below blows cut chaff into a curved air column horizontally placed, and then into a hood. There is provision for insertion of another double screen of appropriate grade to further size the cleaned seeds. All the screens are kept in vibration. A clipper seed cleaner (OTRI) of capacity 2.5 tonnes/day consists of three screens, which can be varied to suit the material, held vertically in constant vibration. Beneath the lowest screen is placed a powerful fan connected through a vertical air column to a hood. The top screen is followed by a scalping spout and the bottom one by a screening spout. Versatile cleaning, sizing and grading can all be achieved. A versatile destoner (CFTRI) removes small stones, glass pieces and other extraneous

material from foodgrains employing a moving belt and differential rolling principle.[86a]

Safflower: The traditional domestic method of seed cleaning, still followed in many ghani and small expeller units processing various oilseeds, is to use a hand tray called a surpa or morram made of plaited cane or bamboo strips. One edge is raised, and this edge diminishes on the two parallel sides. To effect cleaning, the seed is flipped up and down with a slight forward movement, when impurities move towards the front, and then over the edge (see Section 7.5, Safflower, p. 235).

REMOVING OUTER COATINGS

Sesame: Deskining (OTRI) of wet sesame seeds was effected with 95 to 100 per cent efficiency on a disc huller fitted with emery discs, one static and the other rotary (600 rpm), with an adjustable clearance. Synchronising the shaker-separator and cyclone separator yielded continuous operation. In another procedure, deskinning (OTRI) was fully effected by passing wet sesame seeds at no pressure through a single-chamber mechanical expeller at a throughput of 5 tonnes/day. Another deskinning procedure (CFTRI) comprises a quick soaking of sesame seeds in hot alkali lye (6 per cent), followed by tumbling with water in iron wire baskets for abrasive deskinning.[86d] Kernels were isolated using running water on an inclined chute, at the end of which stones were trapped on a weir, over which the lighter kernels flowed.[95,96]

Cottonseed: This seed carries outer lint and a hard inner seed coat. A delinter (OTRI) was specifically designed to remove lint, which had earlier been rendered friable by exposure to hydrochloric acid, through abrasion between two moving belts. The system is similar to that described above for the deseeding of sunflower heads in a continuous thresher. Residual lint was reduced from 9 to 2 per cent. The well-known Bauer disc dehuller using metal discs was reduced in cost with a wooden dehuller counterpart (OTRI), which gave comparable performance (30 per cent coarse meals in both). The wooden discs, one stationary and the other moving, with an adjustable gap, are 2.5 cm thick and 46 cm in diameter, and are enclosed in a metal case which is fed through the centre. Though wear and tear is admittedly high, these discs are cheap and can be made locally.

Coconut: The age-old method of dehusking the whole coconut on a sharp stake driven into the ground still holds its own, and as many as 1500 to 2000 nuts can be dehusked by one person in a day.[45b] Thereafter the nut is split in two by one sharp blow from a heavy knife, the rate here being 7000 per person per day.[45b] No mechanical device for either operation is commonly employed in India.

Maize: A degermer for maize has been developed (CFTRI) by replacing the brake plate of a rice huller with one bearing a serrated edge; when maize tempered with 5 per cent water, and then conditioned for 15 minutes, is hulled, both dehusking and degerming occur simultaneously.[86c]

Neem: A sweetish pulp envelops the neem seed: birds eat this, and the clean seeds dropped on the ground are collected by sweeping. More often however, what is collected is the whole fruit with the pulp on it partly dried to a rubbery texture, and difficult to remove. Un-depulped seed is in turn difficult to decorticate. The classical methods of depulping neem fruit were either to soak in a pit, followed by trampling,[46] or, where water was not easily available, to coat the seeds with mud or ash, leave them heaped for a few days, and then trample.[97] Placing the semi-dried fruits on hard ground, and rolling them below a wooden plank, was another procedure.[46] The ordinary wheat-grinding stone quern (chakki) was especially effective for dried, undepulped neem seeds, and even animal-driven querns were employed for large seed quantities.[46] Abrasion of soaked fruits between the hands, or against a rough coir mat or strong rough sieve, was also practised. The fruits held in bamboo baskets could be freed of pulp by holding them below flowing canal or river water.[97]

Refractions in collected neem fruit are often as high as 28 per cent and their removal has been attempted by floatation in 20 per cent brine (HBTI).[98] Another technique was to move the fruits on a 5° incline in a free stream of water, trapping the heavy impurities on suitable obstacles (HBTI).[99] Cleaning has been combined with depulping. One *depulper* (KVIC) consisted of a hand-rotated cylinder of wire, with its lower half dipping in an open half-cylinder filled with water; the pulp was shredded away by constant abrasion against the rough wire.[160] Another tank depulper (KVIC) consists of sieves placed below water in tanks, on which the fruits were first soaked and then abraded.[100] Half the weight of fruit was returned as depulped seed.[101] In a practical depulping operation, neem fruits were kept under water in tanks for three days, placed in tubs and trampled in another tank, and then supported on a sieve and washed with water; this proved to be a labour-expensive method.[102]

Decortication

General: An all-purpose hand-operated decorticator developed in 1957 by M.A. Sharp under the India-University of Tennessee Technical Assistance Programme consists of vertically-mounted discs faced with 0.94 cm sheet rubber.[103,104] The rotating disc had curved radial feed grooves cut into the rubber facing. Feeding was effected at the centre above the discs through a hopper, and a handle actuated the belt drive. The unit could decorticate 34 kg of castorseed or 23 kg of mahua seed in an hour. Several versatile decorticators (KVIC) were designed for both hand and power operation as aids to village level industry.[83,105,106] A hand-operated unit (KVIC) consists of a solid wooden roller, covered with wire netting, turned with a handle.[107,108] An S-shaped piece of expanded metal serves as a stage, and can be adjusted both upwards and sideways to suit the seed size. Nut entry is controlled both by an adjustable gate in the hopper, and the vibration created by a grooved roller rotating below. Working with groundnuts, three passes yielded total decortication without any kernel breakage. For

subsequent ghani pressing, which optimally needs some hulls, two passes yielded a suitable percentage mix of kernels 55, whole seed 29 and shells 17, from which the shells were easily winnowed away. Because of the smooth gear system, one man could process with ease 65 kg of groundnuts in an hour. In a later design, a spring-loaded foot-press permitted stones to fall out without causing jamming. A power-operated decorticator (KVIC) is of the double-roller type, totally made of metal and particularly effective for hard seeds like neem, for which it was originally developed.[81,83]

Rape-mustard: The technique developed (CFTRI) to dehull these tiny seeds consisted in first sizing the seeds by passage through a vibrating 16-mesh sieve to remove really small seeds, and then conditioning the seeds to a moisture content of 3.5 to 4.5 per cent; this step served to minimise formation of fines to 6.5 per cent during the subsequent steps of crushing in rollers, sieving and air-classification (kernels 70, and hulls 16 to 20 per cent).[109,110]

Castor: This seed is usually crushed whole in India, whether in ghanis or expellers. Decorticators are occasionally used when oils of exceptionally light colour are in demand. Size segregation of seeds on appropriate shaker sieves is followed by cracking between adjustable smooth rolls suitably spaced, followed by air-blowing to remove the light hulls. Abrasion between discs is another route to decortication.

Safflower: Prior to crushing in a ghani, safflower seed is always fully dehulled through a series of operations (Sec. 7.5, p. 235). An improved grinder (KVIC) has been fitted with ball-bearings so as to create a slight gap between the stones, while also making for considerably easier rotation by hand. Safflower and khakan seeds yield well-separated kernels and shells on this unit.[111] As described in Section 7.5, the ground mass is then repeatedly sieved to discard hulls, and finally winnowed in an ingeniously created draft of air.

Modern units for these operations have been devised. A horizontal grinder-dehuller (OTRI) uses two circular grinding stones as in a traditional chakki, but the top unit is driven by power through a shaft and pulley, and can deal with 3 tonnes/day. A vertical dehuller (OTRI) carries two discs of steel with an adjustable clearance, one static and the other rotating at 600 rpm, which yield meats with just 5 per cent hulls. Small commercial grinders as described in Section 7.5 are of both vertical and horizontal design, and are made either of stone or of steel.

The repeated sieving that is necessary after grinding is achieved in practice (as described in Section 7.5) in a set of six shaker-sieves of different mesh size, followed by resolution in fan-operated winnowers.

Groundnut: From the very inception of groundnuts into India about a century ago, the need for decortication was apparent. Beating with wooden sticks or mallets was a practice long established for other crops, and mechanical devices appeared only early in this century. These consisted of a central shaft carrying radiating arms topped with flat pieces, which were

rotated by hand within a drum (see page 35). Power-driven units for large-scale decortication usually consisted of a beater with projecting arms ending in loose corrugated flat pieces (Fig. 29); these worked against a semi-circular grate built-up of spaced bars or upright spaced flats, through the gaps in which the whole mass passed for subsequent separation of kernels and broken shells by blowing using air. The rasp bar grate was found to produce less broken kernels than one of the peg-type (IARI), especially if the grates were enclosed in rubber.[112] Kalyan-type groundnut decorticators of roller grate design have been in commercial use from the beginning of this century; they were rapidly adopted since such kernels fetched a better price than those shelled by hand.

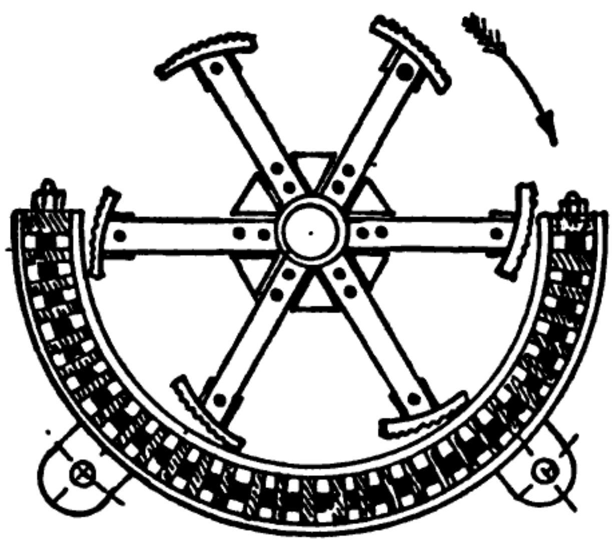

Fig. 29. Early design of grate-type decorticator for groundnuts-in-shell (Source: Groundnut Marketing Report[89])

KVIC-designed decorticators for groundnuts have been described earlier as general-purpose units (p. 250).

A roller-type decorticator (OTRI) of the Kalyan type has been adapted to the triple purpose of decorticating, decuticling and degerming groundnuts. The beater has horizontal channel grooves, with or without steps on the surface. The clearance between beater and grate is adjustable to achieve all or some of the functions desired. Total decortication, 97 per cent skin removal and 92 per cent germ detachment was reported. A beater-type decorticator (OTRI) also effects these triple functions through a beater with projecting arms, rotating coaxially in a trough. A fan blower fixed at the exit separates each component of the mixture. Decortication is total, and reported yields of kernels (free of skins and germs) was 68 per cent, of shells and skins 28 per cent, and of germs 4 per cent. A disc-type unit (OTRI) for decuticling and degerming groundnut kernels is made up of two wooden discs, one static and the other rotating at 600 rpm, with an adjustable clearance. Coupling with suitable screens and a cyclone separator achieves continuous performance with an efficiency, under

optimum setting conditions, of 99 per cent decuticling and 95 per cent degerming.

As part of a larger operation to produce edible flour, groundnut kernels were decuticled and degermed (CFTRI) by roasting the nuts at 80° to 90°C for 10 minutes so as to render the red skins friable, followed by abrasion between rough moving belts or rubber-coated rollers.[113]

Soybean: The black soybean, still important in India (page 73), has an exceptionally tough hull which is quite dehiscent to the kernel. A disc-type dehuller (OTRI) for black soybeans has emery discs 46 cm in diameter and 2.5 cm thick enclosed in a metal case, with an adjustable gap between them. The feed hopper is positioned above and opens on the rotating disc. The mixture passing out is resolved using suitable perforated screens on a shaker-separator, uncut seeds being segregated from dehulled material by first using slots with a width of 2.38 mm, and later a cyclone separator. Between 82 and 84 per cent pure meats and 9 to 9.5 per cent hulls were obtained, with 98 per cent dehulling. Another dehulling procedure (CFTRI) consists of first mixing black soybeans with 10 per cent moisture, tempering for 30 minutes, and heating at 100°C for 10 minutes. This sequence serves to soften the hulls and to detach the kernels internally from the hulls, eventually permitting cleaner dehulling. In commercial practice, some black hull specks do pass into the kernels and are eventually visible in the solvent meal.

Sunflower: The disc-huller *dehuller* (OTRI) with emery discs, described above for soybeans, was effective in removing the hard coats of sunflower seeds to yield coarse meats 70, fine meats 11.5 and hulls 17.5 per cent. Commercial dehullers for cottonseed were effective in dehulling sunflower seeds (CFTRI). In commercial practice in India, both bar hullers with knives, and abrasive disc hullers, are in use.

Rubber seed: Use of the general-purpose power-operated metal *decorticator* (KVIC) (earlier described on p. 250) for rubber seed required the fitting of double metal rollers carrying broad teeth, with a gap between them of 1.5 cm, a depth of 1.00 cm and an inclination of 45° (p. 260). This is in contrast to the small-toothed rollers required to efficiently decorticate seeds like neem, pisa and pilu.[83]

Neem: Both the *hand-operated* and *powered decorticator* (KVIC) described earlier as general-purpose decorticating units were developed specifically for neem seed decortication. When dried neem fruits carrying semi-dried pulp required decortication, they were first freed of foreign matter like stones by water-floatation, then dried to crispness, and sieved. Thereafter decortication followed by sieve-separation yielded kernels, husks and some undecorticated fruit, which was recycled.[81]

Sal: Sal fruits as collected carry five unequal wings which are really the segments of the calyx (Plate 9). On drying, these wings become quite brittle, and are sometimes removed even in the forests by setting fire to them since they burn readily. Following this the brittle seeds are decorticated by rolling below a wooden plank, or beating with wooden sticks.

A *decorticator* (OTRI) of the Kalyan type has been utilised, with a roller beater, a trough-like grate made of round rods or flats, an inclined plane to receive the material, and a fan blower for winnowing. The beater is made of cast iron and has external channel grooves, but a wooden beater is equally effective. The fan blades are mounted on a steel axis which revolves on bearings at either end, but at a different speed from the beater through coupling with a pulley of different diameter. The *hand-driven* small model has a capacity of 1.5 tonnes/day and the *powered unit* of 2 tonnes. A *scaled-up model* for commercial mill use has a 20-tonne daily capacity. A portable *hand-operated unit* (HBTI) has also been developed for field use in decorticating sal seeds.[114]

Gokhru: The gokhru fruit has a hard tenacious cover with flexible thorns, and is difficult to decorticate on standard machinery. A *decorticator* (OTRI) specially designed for the purpose carries a large stationary wooden corrugated disc and a smaller wooden rotating disc, also corrugated. The fruit is decorticated between the discs and falls down, and the small seeds can easily be separated. Soaking the thorny fruit in 2 per cent sulphuric acid for 10 hours, and sun-drying for a day rendered the cover and thorns brittle, and led to total decortication yielding 33 per cent kernels and 67 per cent hulls. The unit is hand-operated and has a daily capacity of 500 kg of fruit.

Mango: Mango stones come with a woody, fibrous, tough outer coating covering the soft inner kernels. A decorticator (OTRI), modified from a commercial copra processor, consists of a cast-iron shaft carrying a number of sturdy cutting ridges 2.5 cm apart, which revolves at 600 rpm in a box of mild steel (Plate 23). The ridges move freely through gaps on one wall of the box, but slice through any mango stone that obstructs them. The shell-kernel mixture falls below into an adjustable damper, and is easily sieve-separated through screens. Both wet and dry stones could be decorticated with equal ease to yield 50 to 54 per cent of kernels in slices.

Shaker-separation and Winnowing

Safflower: The ingenious sieving operation traditionally followed is described for safflower seed in Section 7.5, and the shaker sieves and winnower now employed in updated ghani processing are noted above as decortication devices for safflower seed (p. 235).

Rubber seed: A double-decker sieving machine (KVIC), when employed for the processing of rubber seed, consisted of two sieves of expanded metal of different closeness, each of which had a separate outlet chute, and a solid iron sheet below with its own chute.[83] By suitable choice of openings, big seed, small seed and refractions were collected from the three chutes with a high degree of segregation. The same siever unit was also employed, after decortication of the rubber seeds, for satisfactory kernel-seed separation (see p. 253).

A winnower (KVIC) was also developed for rubber seed processing since the kernel and shell were found to be of almost the same weight. A 3-step pulley permitted three speeds of revolution of the fan (820, 580 and 380 rpm), and upright planks, whose height could be varied, provided obstructions to the airflow. By suitable combinations of speeds and planks, the material was separated into kernels of high grade, kernels of lower grade (which could be reprocessed), and shells (see page 260).

Musk melon: A small shaker-sieve unit for separating musk melon hulls after decortication has been devised (CFTRI).[114A]

PULVERISATION

General: The power-operated general-purpose decorticator (KVIC, see page 251) of the double-roller type is made totally of metal and has detachable rollers.[83] Replacing these with metal rollers of smaller diameter and with less pronounced indentations furnishes a powerful pulveriser. Since the gap between the rollers is adjustable, the unit can also be employed to disintegrate a variety of oilseeds and their kernels.

BENEFICIATION

Air-classifiers: The protein content of edible sesame cake was raised from 50 to 65 per cent by air-classification (CFTRI), and the fibre level simultaneously reduced.[93,94]

Ricebran: This light material can be beneficiated in an air-classifier (OTRI) consisting of a conical vessel to the top of which is connected a long pipe of moderate diameter ending in a T. The bottom of the cone rests on a perforated iron plate, and to this is attached, by way of a bend, the narrow end of a reverse cone. A small door is provided just above the perforated plate. Beneficiation in this unit of ricebran containing 18 per cent sand and silica yielded 72 per cent of material with just 6 per cent of sand and silica. Two other fractions were obtained: one was mostly heavy sand and silica, and the other was a 27 per cent fraction with a high content (27 per cent) of sand and silica.

A working procedure to upgrade the quality of ricebran derived from stone rice shellers during production itself has been devised (Hindustan Lever Ltd).[115] Normally, during this operation, a grooved stone cylinder rotates in a casing carrying a shearing blade in the first pass; thereafter, the hulls may or may not be removed before putting the mass through the second operation. By detaching the shearing blade during the first pass, and also removing the shearings from the rice mass, the second pass when carried out after refitting the blade, gives about 15 per cent of the total bran as a product of high economic value suitable for solvent extraction, which huller ricebran is not. Ricebran as produced generally carries broken rice and germs. A process (CFTRI) has been devised to separate these from bran.[86a]

Steam distillation: A unit was designed (KVIC) for 95 per cent recovery from mustard cakes of the volatile pungent isotheocyanates present, after

first ensuring their total release by keeping the meal with 8.5 per cent water at 40° to 45°C for 60 minutes.[116] These spicy products would find use in table sauces and pharmaceuticals, while the feed quality of the cake would also be improved.

Cooking

General: A general-purpose *cooking kettle* (KVIC) consists of a jacketed rectangular metal tank, the annular space of which is filled with water that can generate steam at 1 kg/sq cm pressure when placed on a brick-built fireplace burning wood or charcoal.[81] The ground material is mixed with warm water and introduced into the kettle, cooked with indirect steam as long as required, and discharged through a low side-door. Oilseeds like sesame and linseed,[80] neem and mahua,[81] and nahor[83] gave higher yields of oil (on subsequent expression in various devices) by such indirect steaming than by direct contact with live steam.

Filtration

General: A filter centrifuge was designed (KVIC) for clarifying small quantities of oil, and comes in both hand- and power-operated models.[37,48,50] The aluminium inner bowl is 14 cm in diameter and 8.5 cm high, with a spill-over protector fitted at the top. An outer jacket surrounding the bowl collects the clean oil. Into the bowl is fitted a double layer of muslin along with a filter paper; these replaced the filter thimble initially tried.[48] A handle speed of 80 rpm maintains 1600 rpm in the bowl. Oil is kept in an upper drum and fed to the centre of the bowl through a polyethylene tube. The capacity is about 30 kg/hr. With most oils one pass is sufficient, but rubber seed oil with a high sediment content requires two passes.[50] Warming the oil helps in its clarification.

Groundnut: A special filtration technique has been devised (CFTRI) for the removal from raw groundnut oil of aflatoxin which is present in considerable amounts in market samples. This consists of a standard plate-and-frame filter press fitted with pads coated with a fullers' earth-salt (1 : 2) mixture. This absorbs 90 per cent of the aflatoxin as the oil is pumped through.[117,118] Exposure to sunlight in thin layers, and washing with 10 per cent brine, were also found to be simple household approaches to decontamination.[119,120]

Total Processing in Novel Ways

Novel procedures and items of equipment for the processing of oilseeds employing aqueous systems to yield both oil and protein of high quality have been developed (CFTRI).

Coconut: Fresh coconut meat rather than copra is employed. By grating the meat, and passage through a screw-press, coconut milk is obtained which is centrifuged to yield oil.[121,122] The aqueous portion on concentration yields a coconut 'honey' rich in protein, sugars and minerals. Equipment for each of these steps was devised or adapted.

Groundnut: Integrated processing of dehusked groundnut kernels was effected by extraction of the oil with slightly alkaline water, followed by centrifuging of the oil.[123,124] Further dissolution in an even more alkaline milieu caused the proteins to solubilise. Further centrifugation yielded the soluble carbohydrates, after which the soluble proteins were precipitated with mineral acid to yield an isolate of high purity. A commercial unit based on the process was established in Bombay in 1967. Optimal conditions for making the various dispersions, and the right centrifugal equipment, were keys to the successful operation of the process.

CHAPTER 9

Processing of Unconventional Oil-bearing Materials

In Section 7.5, the processing in ghanis of staple, conventional oilseeds, constituting Groups A and B, has been discussed since this is unique to India. The processing of these oilseeds in expellers or solvent plants is fairly well-known and documented, and will not be considered in this book.

It is with the processing of the less-known, non-conventional oil sources of India that this chapter is concerned. These oil-bearing materials have all along been considered in the following groups:

Group C : Oil-bearing materials derived as byproducts of cultivated crops
Group D : Oilseeds with unusual lipid associates
Group E : Oilseeds carrying vegetable hard fats
Group F : Oilseeds carrying soap-making oils
Group G : Oilseeds with oils of unusual nature
Group H : Oilseeds from shrubs
Group I : Oilseeds from trees that yield other commercial products
Group J : Oilseeds from fruits
Group K : Oilseeds from vegetables

In the processing review which follows, the nine oilseeds constituting Group C will first be considered together. Though these materials are processed in India essentially in conventional ways, they rate attention as being rather unfamiliar materials.

The rest of this chapter will be devoted to the processing of oilseeds from the other Groups, D through K. These materials have been processed in various ways, in ghanis or chappas, or by small-scale techniques of hydraulic pressing or hand-screw operation, or more recently by modern expelling and solvent extraction. A few have only been experimentally processed, and others are included in hope of their commercial potential.

9.1 Processing Oil-bearing Materials Derived as Byproducts of Cultivated Crops

The oil-bearing materials that will be considered in this section are

those which arise as byproducts of cultivated crops, classified as Group C in this book.

C1. RICEBRAN

Commercial processing of ricebran for oil has established itself firmly in India during the last decade. Some 1.5 million tonnes of the bran were collected in 1986 and processed to yield approximately 210,000 tonnes of oil, of which about 90,000 tonnes were of edible grade.

Upgrading of the raw material is frequently necessary to get a product that justifies solvent extraction. The means of doing so during production of the bran itself and after it has been recovered, have already been described (page 247). The very rapid development of free fatty acidity, up to 10 per cent within 24 hours of bran removal from rice, also implies that the bran must be stabilised immediately if the recovered oil is to be of edible quality. The means for achieving such stabilisation have also been earlier outlined on page 247. If the stabilisation is to be effected at the solvent unit, the bran should reach there without delay from the rice-processing units. Parboiling of paddy, one of the methods employed to increase rice out-turn on milling, also has the consequence of stabilising the bran, and in practice most of the edible grade of low-acid ricebran oil is produced from parboiled bran.

For solvent extraction, the bran must first be pelletised to achieve flake strength, minimise fines in the miscella and reduce solvent losses. Pelletising is adversely affected by the presence of coarse particles like husk and broken rice. By sieving these away, and effecting controlled cooking, followed by drying with evaporative heating, the ricebran becomes crisp, and amenable to excellent pelletisation in commercial solvent plants.[125] An innovative method is to pass the ricebran under pressure through an expeller; when it emerges, the sudden reduction of pressure crisps the product.[126] Likewise emergence through a die-plate yields excellent pellets.[126]

Though *hydraulic pressing* at an elevated temperature will recover about half the oil present, only solvent extraction with hexane is practised in India.[127] The average yield of solvent oil from the grade of bran available is about 14 per cent.[65]

C2. TAPIOCA SEED

Though not normally allowed to set for fear of reducing yields of the edible tuber, tapioca seed is produced, like castor seed, three to a capsule. In fact it resembles the latter seed in appearance, being about 10 mm long, 6 mm wide and 4 mm thick.[128] The hulls constitute 50 per cent, and carry 7.6 per cent protein and 60 per cent crude fibre. Direct crushing without decortication in a ghani yielded 11 per cent oil, and in a laboratory hydraulic press 15 per cent, out of the 26 per cent present.[128] Decortication in cracking rolls as with castor seed should be quite feasible, and the kernels (oil 49, crude protein 29.2, crude fibre 2.2 and total ash 4 per cent)

should likewise be amenable to expelling and solvent extraction to yield a meal of high quality.

C3. MAIZE GERM

The processing of the germs, removed from corn during its conversion to starch by wet milling, to yield corn oil is a well-established industry in several countries. Expelling of germs yields from 25 to 47 per cent oil, and commercial solvent extraction a further 11 per cent of oil.[65]

C4. TOBACCO SEED

These very fine seeds, usually black but sometimes yellow, look almost like dust.[129,130] They carry much extraneous matter, which can be removed on 30, 50 and 60 mesh screens. Direct crushing of the whole seed (oil content 37 per cent) twice in expellers yields 25 per cent oil, but flaking in smooth rolls can raise the yield to 30 per cent in one pass.[131] Optimum moisture contents were 4 per cent for a single crushing and 5 to 9 per cent for double crushing, both being performed after cooking the seed to an initial 6 to 10 per cent moisture level. Increasing the worm speed from 7.5 to 10 rpm was found to save 40 per cent time in a single crushing and 25 per cent in the two-stage operation.

C5. RUBBER SEED

The decortication of rubber seed in a decorticator carrying two metal toothed rollers has been described, as well as the double-decker sieving unit for subsequent separation (page 253). It was found that rollers with a 45° inclination yielded a product mix carrying only 2 per cent undecorticated seed and 3 to 5 per cent broken kernels.[83] For sieving, mesh or expanded metal sieves of 15 mm on the top deck and 12.7 mm in the lower one gave excellent separation. Processing of rubber seed in a vertical hand screw-press (page 242) yielded 62.6 per cent oil, and 66.8 per cent in a steam-jacketed metal ghani operating at 60°C.[50] Crushing in a hydraulic press (page 244) after cooking with indirect steam yielded 44 per cent oil in two pressings,[83] and a hand centrifuge (page 256) fitted with special filter thimbles gave oil of excellent clarity.

Modern processing of rubber seed involved mechanical decortication on a grate-type Kalyan decorticator with the grates suitably arranged.[132] Both whole seed and meals could be cooked and expelled without special difficulty to yield 9 and 13 per cent oil against the 24 per cent present in whole seed. Storage of kernels leads to a pink discolouration and to reduced yields of expeller oil: this is perhaps by oxidation-polymerisation of the oil, which contains 16 per cent linolenic acid.[132,133] Solvent extraction of expeller cake without storage could doubtless be practised.

C6. TUNG SEED

Indian-grown tung seeds, *Aleurites fordii*, come in a range of sizes, 37 to 48 mm in diameter and 13 to 25 g in weight.[134] Dehulling in a Bauer

disc huller carrying plates of grooved steel yielded several products: split kernels (total 31 per cent), large-sized outer shell pieces, a mixture of outer hulls and inner hulls, shells in crumbled form, and a fine dust which escaped into the air and settled on the machine parts. The boiled kernels were easily separated, further reduced in smooth rolls, or again in a Bauer huller, and then expelled twice to yield 17 per cent oil, leaving 9 per cent residual oil in cake.[134]

Storage of fruit decisively affects the oil yield. Tung kernels turn brown on storage, and the hexane-extractable oil content goes down from 62 to 51 per cent after 240 days at ambient temperature.[135] Low-temperature storage caused no such reduction. The normal expelling yield of 17 per cent from whole seed dropped to 12.4 per cent in 160 days and to 4.8 per cent in 250 days, so storage of seed for more than 100 days is not desirable. Neither is storage of cake for more than a month, because of the danger of spontaneous combustion.

C7. JUTE SEED

Jute seeds from both varieties of Indian jute, *Corchorus capsularis* and *C. olitorius*, are very similar in containing 13 per cent of oil and in respect of their processing.[136] The seeds were flaked in smooth rolls, and processed both in an expeller and by direct solvent extraction. The oil in the seed was found to be in excellent condition even after a year of seed storage.[136]

C8. SPENT COFFEE GROUNDS

These grounds represent the residue from the extraction of roasted coffee beans to yield so-called instant or soluble coffee. Solvent-extraction of spent grounds yielded about 9 to 17 per cent oil.[137] The commercial grounds (passing 12 mesh and retained on 20 mesh) were flaked to 0.38 mm between closely-aligned smooth rolls. Such flaking doubled the yield of oil obtained by subsequent solvent extraction. Even passing the spent grounds through an expeller improved later extraction with hexane. Cooking the flaked grounds with 12 per cent moisture was superior to cooking them with 16 per cent moisture, or to extracting them cold.

In soluble coffee manufacture, grounds are produced as a sludge with a moisture content of 75 to 80 per cent. Such sludge develops internal heat on heaping or storage in gunny bags, which leads both to putrefaction and to hydrolysis of oil. Drying the grounds in the sun or artificially was recommended to obtain oil of improved quality.[137]

Spent coffee grounds are commercially solvent-extracted in India today in a small way, some 14 tonnes of oil and 224 tonnes of oilcake having been produced in 1985.[65]

C9. TEA SEED

Tea seeds are of medium size, varying in diameter from 20 to 25 mm and in weight from 0.5 to 2.2 g each.[138] The hull-to-kernel ratio is

30 : 70. The seeds were cleaned in a 3-tier mechanical (clipper) cleaner, and decorticated in a roller beater against a suitable grate (page 252) with spacings slightly smaller than the seed size, to give kernels still carrying about 16 per cent hulls. A disc huller also removed hulls, but yielded kernels in powdery form. The oil yield (16 per cent) in an expeller was highest, and the time of crushing least, when meals with about 5 per cent hulls were crushed.[138] Solvent extraction would doubtless remove the remaining oil (8 per cent).

The cake is bitter through the presence of saponins. This, and the low protein content of 10.8 per cent, suggest its use as an organic fertiliser for crops prone to insect attack, and as a soil conditioner.[138] The hulls removed could be added back before such use.

9.2 Processing of Oilseeds with Unusual Lipid Associates

General

That the ancient plants described in Part A bore seeds which carried oil was well-recognised. Hermits who renounced the world to live in forests away from human kind, a recognised last stage of the ideal life, were expected to subsist on food like berries and roots which grew without the agency of man. Tribal peoples living away from civilisation have always exploited tree seeds like mahua for fat. Even today, when forest produce is under government control, the right of collection is granted to them. Similarly, use of sal seeds in the forests of Orissa and Himachal Pradesh where these trees abound is a right of local tribals.

Two common methods are in use for winning the fat from such seeds. One is pressing in a chappa made of tree trunks or wooden planks which was considered in Section 8. The other is to pound the seed into fragments or powder, boil in a vessel of water to release the fat, and skim it off from the surface either hot or after it has set. As it happens, several tree-seed fats are solid at ambient temperatures, like mahua, sal, dhupa and kokum.

More sophisticated means of crushing to meet community needs are also quite ancient. Kautilya's *Arthasastra* of 300 BC states that one of the duties of the superintendent of the storehouse, the kosthagara, was to supervise the accounts concerning the manufacture of rice, oil and the like, collectively termed simhanika.[12c] Sesame, linseed and safflower seeds are listed, and also neem, mahua, ingudi (*Balanites aegyptiaca*), kapittha (*Limonia acidissima*, the wood apple) and kusamra, whose identity is not known.[12b] Even the yields of each of those oils on the weight of seed are given in terms of one-sixth, one-fifth and one-fourth. Occurring in a commercial context, this must imply a crushing technology.[12b] This is reinforced by mention of the pestle and mortar among the necessary instruments.[12b] The processing of non-conventional oilseeds of different types may now be considered individually within their groups.

D1. NEEM FRUIT AND SEED

Storage of fresh neem seed has the curious effect of raising its crushable oil content. A storage period of 33 months was stated to raise the oil content from 36 to 42 per cent,[139] and in another study the value went up steadily from 39.4 to 45.7 per cent.[140] Soon after depulping, neem seeds are believed difficult to extract, and storage of the thoroughly-dried fruit for at least two months prior to processing is recommended.[141] Opinions differ whether this is best done as whole dried fruit, the commodity available in north India, or as depulped dried seed, the commodity of the south, but the conflict may be explicable on the ground of insufficient drying. In one study, the yield of kernels on decortication of dried fruit was 93 per cent against just 63.5 per cent from depulped dry seed:[142] an editorial footnote to the paper points out that this is contrary to the extensive experience with neem seed in Tamil Nadu in south India.

The depulping of fresh neem fruit has been described earlier (page 250).[97] However for subsequent decortication, depulping is not essential, and dried whole fruit can be employed.[140] Traditional methods included rolling between wooden planks, or in stone grinders (chakkis), or in flour mills after adjusting the gap between the stones. The power-operated decorticator (KVIC) employed has twin corrugated rolls, and decortication (yield 30 per cent) is followed by sieving of the kernels and husk as a single fraction, followed by winnowing to separate the kernels, which bear 45.9 per cent oil.[81] These were cooked twice using indirect steam, and yielded on screw-pressing 33.7 per cent oil. Screw-pressing followed by ghani pressing yielded 39.5 per cent oil.[81]

Ghani pressing of neem seed is mentioned in the *Arthasastra* of 300 BC, and a 20 per cent yield is noted.[12b] However there are difficulties of cake formation, and special means are necessary. In some very old wooden ghanis at Ongole in Andhra Pradesh used for neem, the pit was lined with wooden strips, which needed changing every two to three months.[143] In Madras state, raw brown sugar (jaggery) is added to the water during ghani crushing of neem kernels, this being the normal practice far sesame seed crushing in south India (page 218), and the pressing operation takes only 40 minutes, leaving just 7 to 13 per cent oil in cake.[97] In neem seed crushing, the pestle tends to be lifted out, and even when weights are applied to the load-beam to prevent this, the yield of oil is low (27 per cent).[144] One corrective is to add 7 per cent of groundnut cake to assist cake formation. Use of a jacketed ghani and crushing at 50° to 60°C raised the yield to 31 per cent oil, averaged over 37 runs. After crushing in a Wardha ghani with a 34 per cent yield of oil, the cake still carried 18 per cent oil,[71b] suggesting that the nature of neem seed does not conduce to full pressing of oil.

Hand-screw pressing of neem seed has been described earlier[81] (page 243).

The crushing of neem kernels in *expellers* is now widely practised. In south India, the traditional preparation of depulped, dried neem seeds was

also earlier practised prior to expeller crushing, but this appears to be giving way to the use of whole dried fruit. The crushing is stated to proceed more easily than with kernels, the yield of oil is good, and the quantity of cake of good manurial value is higher.[143] Both baby and large expellers are used, and the material is decorticated and ground, for example in rice hullers, before expelling. Data on neem oil production in expellers are lacking.

Solvent extraction of neem appears to be carried out directly on flaked seed; the production of oil in 1983-84 was 10,957 tonnes and that of meal 62,600 tonnes.[65] Expeller oilcake is utilised directly, and does not seem to proceed for solvent extraction.

D2. KARANJA SEED

Traditionally karanja pods, which are flat, elliptical, and about 8 cm long, are quite dry, carrying no pulp at all. These pods are decorticated easily enough by beating with sticks or wooden mallets to release one or two flat, kidney-shaped kernels.[145,146] The thin brittle cover on the latter is not removed, but would probably yield to the roasting and deskinning treatments developed for oilseeds like groundnuts. The oil content of the kernels being 35 per cent, ghani crushing is feasible.[145] Oil yields on a ghani are 18 to 22 per cent, and in an expeller 24 to 26 per cent. Difficulties if any have not been recorded.

There may be some desultory ghani crushing of karanja seeds today, and also perhaps some expeller crushing on contract by seed-collecting agencies like the KVIC. In recent years, some 10,000 tonnes of karanja seed has been annually processed by direct solvent extraction.[65]

D3. KUSUM SEED

The market commodity is neither pod nor seed, but the clean kernel of reddish-brown colour.[147] The kernels are soft and oily to the touch, and susceptible to fungal attack.[148] Storage of kernels for over four months results in deterioration, and is not recommended,[149] though the seeds themselves, rather surprisingly, are stated to retain their viability for two years.[150]

Powdered kernels are used for extraction. This is done in a traditional dhenki, a wooden see-saw pounder mounted on a fulcrum (p. 80); one end is depressed with the foot, and then released to come up, and the other end has a hammer attached for pulverisation.[149] The kernels or even the whole seeds are roasted in a pan till friable and powdered; and the mass is then boiled in water till the released oil floats on the surface. Yields of 32 to 35 per cent are mentioned.[149]

Elsewhere, the powdered kernels are steamed in a bamboo basket or gunny sacking, and then pressed for oil in a chappa, with a recorded yield of 25 to 27 per cent.[149]

Ghani crushing employs added hot water to assist in release of oil; the mass is repowdered after one crushing, more hot water sprinkled on it

and the mass crushed again to yield 25 to 27 per cent oil in the first operation and a further 2 to 5 per cent in the second.[145]

Expeller yields are stated to be 36 per cent.[145] No special difficulty is recorded.

Both ghani and expeller extraction appear to have dwindled. In recent years some 5,000 tonnes of kusum seed have been processed annually by direct solvent extraction, but the reported yields of solvent oil of about 11 per cent appear unduly low, unless they have been expressed on total pods as the raw material utilised.[65]

D4. NAHOR SEED

The thick fibrous outer coat or pericarp of the fruit is about 3 mm thick, and the seed is either a single round one 20 to 30 mm in diameter and 2 to 3 g in weight, or two or three flat compacted hemispheres.[148] The seeds constitute some 70 per cent of the fruit, the shells 41 per cent and the kernels 29 per cent. The seed has 45 per cent oil and the kernel 75 per cent,[148] but the range appears to be wide: seeds from Assam had 45 per cent, from Kerala 46 and from West Bengal 35 per cent.[146]

Traditional decortication appears to be desultory, and leads to a mixture of dried fruits still undecorticated, seeds and shells.[148] Drying prior to decortication appears to be insufficient, since in one study, 30 per cent of the seeds were found to have been damaged by insects, though neither fungal growth nor germination had occurred.

Prasad Rao and Shrivastava made a thorough study of the total processing of nahor seeds.[148] The mix of dried fruit, whole seeds and shell that was received was first resolved using a double-decker sieving machine into two sieve sizes (spage 254) to yield about a third as almost unmixed seeds. Round seeds could be separated from flat seeds by winnowing to yield equal quantities of each. Only round seeds were processed further. Decortication in a double-roller metal unit (Section 8.2, p. 251) followed by winnowing on a fan-blown machine yielded kernels in three grades. The presence of two types of nahor seeds would complicate commercial decortication. While bold seeds of good quality yielded 61 per cent kernels, the presence of insect-damaged seeds caused this to fall to 51 per cent *in toto*. Shells constituted 44 and outer fibrous shells 5 per cent.

Ghani crushing of either pure kernels, or even of kernels with 16 per cent of added shells, was a failure through poor cake formation.[148]

Hydraulic pressing of nahor on a hand-operated KVIC unit (Section 8.1, p. 244) proved feasible. The mix of kernels with 16 per cent shells could not be powdered between rollers because of stickiness and frequent jamming, and a power ghani was employed for the powdering operation. The powder was cooked at 90° to 95°C for 20 minutes with indirect steam, and subject to a hydraulic pressure of 25 kg/sq cm to yield 51 per cent of the oil present. Direct cooking of pure kernels with steam, followed by hydraulic pressing, gave similar yields.

Expeller pressing was stated to yield less oil than did hydraulic pressing.[148] A conventional practice is to employ some ricebran during expeller-pressing to ensure a better grip.[145]

D5. UNDI SEED

The fruits of the undi come in two sizes, 17 g and 9 g, and sun-dry to half their weights.[145] Dried seeds are vended, according to number, by village farmers who own the trees, or by children to the village vendor.[151] In Orissa the seeds are collected by labourers and disposed of in public auction,[146] sometimes after traditional breaking with a light hammer or rolling under a flat board.[145] The kernels may even be further sliced in two and dried in the sun for four to five days. On a decorticating unit, a 51 per cent yield of kernels is obtained.[145]

Undi kernels are extremely rich in oil (73 per cent). Ghani crushing is reported to yield 59 to 63 per cent of a bluish-yellow oil, but crushing details are not available.[145] Other reports describe the oil as dark green, viscous and of disagreeable odour.[152a] Expeller crushing is stated to yield 5 per cent more oil than in a ghani.[145]

D6. RAYANA SEED

The seed from this hill-growing tree has about 78 per cent of kernels rich in oil (47 per cent). The oil is stated to be had by roasting and bruising the seeds, followed by boiling with water, when the oil floats to the top.[10e]

9.3 Processing of Oilseeds Carrying Vegetable Hard Fats

E1. MAHUA SEED

Mentioned by Kautilya, mahua seeds have long been recognised as easy to decorticate, and amenable to ghani crushing. Even in modern times, the seed has been an article of commercial trade. Thus in 1899-1900, mahua kernels worth Rs. 100,000 were exported to France, Bulgaria and other countries.[68,151] In 1949-50, as much as 100,000 tonnes of mahua seed were stated to have been collected, of which 10 per cent was noted as being crushed in ghanis.[64] A recent estimate suggests that ghani crushing of mahua seed has now practically ceased, having been supplanted by modern methods.[65]

Seed storage has profound effects. Only unripe fresh seeds, which are white and wet, extract well: since such seeds become available at the start of the rainy season in June, this is the best time to crush.[36c] Traditionally, fresh seeds were decorticated using sticks or stones immediately after collection, when this operation is simple. Storage causes the shell to harden, and decortication becomes difficult.[138] Moreover, storage of the whole seeds frequently leads to fungus attack. Though well-dried kernels apparently store well, it is difficult to crush stored seeds in ghanis.[139] Even seeds that are ripe, red and dry are stated to be difficult to crush: frequently a bind-

ing agent like mahua flowers is added, and so is extra water, though in just half the quantity required for traditional oilseeds. Dehydration of just-ripe mahua kernels caused by maturing or storage seems to lead to some change in the protein-fibre structure that results in a tighter hold on the oil present.

A 20 to 30 per cent yield of mahua oil is obtained in a ghani.[71c] In tribal areas mahua seeds are frequently extracted in chappas.[141,153] Seeds are steamed for about 30 minutes in a plaited basket or envelope,[71c] which is then extracted under pressure between wooden planks (Section 8.1).

A hand-screw press is also well-suited to crushing mahua[81] (page 243). A decorticator of Sharp design performed admirably on mahua seeds[138] (page 250).

Processing of mahua kernels in expellers, followed by solvent extraction, offers on difficulty. In fact practically all mahua seed appears to be so processed today, with the expeller cake passing directly to solvent plants.

E2. SAL SEED

From being a curiosity, the processing of sal seed became an industrial reality in India during the last decade. There were several reasons for this. The fat itself had high commercial potential as a substitute or extender for cocoa butter, and the trees grow in vast forest stands which facilitated seed collection by timber contractors with exclusive rights. Promotional measures, and research and development efforts, were also forthcoming. A market for the cake both at home and abroad was built up. As a result some 100,000 to 150,000 tonnes of sal seed have been processed annually by solvent extraction in recent years.

Sal seed is actually a dried fruit, with five sepals extending upwards as wings (Plate 9). On sun-drying these become friable, and are easily removed to yield the kernels as two to four pieces in about 50 to 66 per cent yield. Decortication was traditionally effected by rolling under a plank or piece of stone, but decorticators of several kinds have been developed. One is a small, portable hand-operated unit for use in the forest,[154] the second a small unit operated by power,[155] and the last a machine of large capacity operated either by two persons or by power[156] (page 254).

Kernel storage from one season to the next poses several problems. One is fungal infection, and the other weevil attack, and stored kernels are now routinely treated with fungicides or aluminium phosphide.[157a,157b] If kernels are insufficiently dried to a moisture level of above 11 per cent, corresponding to 70 per cent relative humidity, storage causes powderiness in the material.[158a] Lipolysis of the fat causes increase in free acidity,[159] while its oxidation leads to the formation of epoxy acids, which in turn hydrate into dihydroxy fatty acids.[157a,160,161] In good-quality fats, glycerides containing these oxygenated acids constitute about 2 to 4 per cent, but they can rise to values as high as 6 to 12, corresponding to a third the quantity of actual epoxy and hydroxy acids themselves.[162]

Fat is extracted by tribals in the state of Orissa by first boiling sal kernels with water, drying and powdering, and again boiling with water to release the fat, which solidifies on the surface. Yields are probably poor.

Ghani crushing of sal kernels is stated to yield 11 per cent of fat and expelling in a hand-screw press 11 per cent, which seems high. Extraction first in a hand-screw press, followed by expeller processing, was however stated to have been unsuccessful.[158b]

Solvent extraction of uncooked kernels, even of fine particle size, was very poor. Flaked cooked kernels of 0.24 mm thickness were reported to be easily extractable to low fat levels.[163,164] Commercial practice consists in cleaning kernels on a shaker-separator to remove foreign matter, followed by size reduction, conditioning with steam to a 15 per cent moisture level, flaking in rolls, and finally extracting with solvent.[158c] Expeller operation followed by solvent extraction is also practised. Some 14 per cent fat and 86 per cent meal are consistently obtained.[65] The latter contains very little protein and also carries tannins which reduce its utility as an animal feed (page 332).

E3. DHUPA SEED

So rapid is germination when the large dry dhupa fruit falls to the ground that each is broken up at once with a mallet or stone (page 100/1). The shell constitutes 40 and the kernels 60 per cent, the latter obtained as fragments of a yellowish colour with pink patches.

In godown storage, these are piled 1 to 1.5 m high on the floor, and frequently turned over for drying.[145] If sunshine is available, outdoor drying may be practised before transfer indoors.

Dhupa kernels are known to be unsuited to ghani pressing of fat. However ghanis are used as a grinding aid in villages.[165] The kernel pieces are cooked with water in brass vessels for two to three hours till they have softened. They are then placed in the pit of a small ghani; the pestle is inserted, and rotated by two men standing across the ghani barrel and passing the pestle from one to the other. The weight beam and the curved pieces are simply detached and laid aside, and not brought into play. The resulting paste is mixed with more water, and boiled in a brass vessel for four to six hours with intermittent stirring. The mixture is poured into cold water in a larger vessel and cooled overnight. The thin solid crust of fat is kneaded into a ball between the palm and fingers. To free it of suspended material, the fat is frequently reboiled once or twice with water. If set aside to cool, it yields grains of solid fat suspended in a yellowish liquid with a green tinge which fades on keeping. Dhupa fat has thus quite a remarkable resemblance to the highly-valued ghee (clarified butterfat).

Yields by these rendering techniques are stated to be poor.[162b,166] In an actual experimental trial, 909 kg of kernels yielded just 18 kg of fat which still carried 25 per cent water, a yield of well below 2 per cent.[167] When rendered in iron vessels, the kernels were found to turn violet or

dark brown, while the dumped water extract was found to destroy grass and plant life; phenolics were suspected to be responsible.

The hand-screw press is reported to have been successful in extracting oil from dhupa kernels.[76] Yields in a hydraulic press are of the order of 14 per cent.[152b]

Solvent extraction of dhupa kernels even after size-reduction to grits is stated to be poor. Expeller pressing to get about 7 per cent fat, followed by solvent extraction, yields 20 to 22 per cent of dhupa fat as a material of tallow-like consistency, pleasant odour and pale, greenish-yellow colour which bleaches on keeping.

E4. KOKUM SEED

The seeds removed from the acidic pulp of the kokum fruit are cleaned of adhering pulp by coating with ashes, drying and rubbing.

Traditionally, seeds are broken with wooden mallets just as for dhupa, and the kernels collected. These contain 44 per cent fat, which is recovered by rendering with water in a yield stated to be 25 per cent.[152c] The fat solidifying on the water is traditionally moulded by hand into a brittle, egg-shaped ball of light-grey to yellowish colour which is solid in markets. It has varied uses: for cooking with, as an emollient for the skin, and as a base for medicated preparations in the manner that ghee is used.

Ghani extraction fails for the usual reasons of lack of cake formation, and the solid nature of kokum fat.

Modern mechanical decortication, followed by expelling, yields from 34 to 44 per cent fat.[145] This is stated to carry an exceptionally high proportion (12 per cent) of its weight of sediment, which can be removed by hot filtration.[145]

Solvent extraction is not likely to present any problems.

At the turn of the century there was considerable trade in kokum fat in the Portuguese settlement of Goa in India.[51e] The fruit itself was called brindao and was much used in preparing acidic drinks and sourish curries; the vindaloo style of cooking pork there, for which vinegar is now employed, seems to have had its origin in sour kokum fruit pulp.

E5. TAMAL SEED

This other *Garcinia* species is far less widely grown than is the kokum, and is mainly a curiosity at present. The seeds have a fat content of 30 per cent,[152c] and the fat is obtained by rendering, for use as a lamp oil and ghee substitute.[51e] Modern processing has not been reported.

E6. PHULWARA SEED

Phulwara or chiura is *Diploknema butyraceae*. The kernel comprises 70 per cent of the seed, and carries 55 to 66 per cent of fat. This was once called phulwara butter, and it is stated to solidify more quickly than mahua fat.[51f]

In villages, the seeds are boiled with water in large pans, decorticated while wet between two stones, and the kernels dried before storage. Later the kernels are roasted and crushed hot in a ghani to yield about 40 per cent fat.[168a] A disintegrator was found to break the seed into several pieces, also achieving decortication, after which air-classification removed the shells (24 per cent). Solvent extraction of kernels yielded 60 per cent fat.

9.4 Processing of Oilseeds Carrying Soap-making Oils

F1. KHAKAN-PILU SEED

There are two botanical varieties of khakan, with slightly differing seeds. *Salvadora oleoides* yields small, bitter seeds that are difficult to decorticate and are therefore crushed as they are. *Salvadora persica* is the variety that is mostly collected, both for crushing and for feeding to milch animals to increase their milk yield. The seeds are 'sweet' and large, and being amenable to depulping, furnish higher expeller oil yields of about 39 per cent compared to the 21 per cent output from the ripe and bitter type, and the even smaller 15 per cent oil yield from unripe and bitter khakan fruits.[145]

The fruits of *persica* or sweet khakan, green when unripe, turn a transparent deep red on ripening. The seeds are soaked in water for four to six hours and then passed through an abrading device to loosen the pulp; if this is not done, the pulp on drying will turn elastic and retard later decortication.[169] The seeds that emerge are rubbed to remove loosened pulp, and again put in water, when the fully depulped seeds sink. Whole seeds and partly depulped seeds float, and are collected and reprocessed. In certain areas, a unit called a lothani, which is a traditional carding device for removing seeds from cotton, is employed first to detach khakan fruits from their branches, and later to effect depulping.[170]

Decortication is not generally practised, even for expeller crushing. The horizontal stone quern or grinding wheel is stated to perform excellently in disintegrating khakan, in fact better than for many other oilseeds. It is stated to be even superior to the Wardha decorticator with its metal bedplate[171] (page 250). The improved stone chakki (KVIC), which has a central ball bearing and a device to adjust the gap between the stones, and is in common use to grind safflower seeds (page 235), is also stated to be useful in decorticating khakan seeds.[100] The husk and kernels are present in the ground material in equal amounts, and the kernels emerge split into two pulse-like pieces.[170]

Even though the proportion of oil present in the kernels is 40 to 45 per cent,[145] ghani crushing of khakan seeds is known to be difficult because the oil is semi-solid and cake formation is poor.[170,172] Use of a flame torch, hot 8 cm balls and added groundnut cake were all suggested, but the use of hot rods or hot balls still resulted in uneconomic operation. Use of 10 per cent water during ghani crushing is reported to have yielded, from

yellow kernels, 30 to 40 per cent of oil; green kernels gave 44 per cent of oil with a strong odour and a greenish colour which was easily bleached yellow by exposure in thin layers in metal trays to the sun.[173]

Shrivastava and Kalookhan describes the processing of the large, sweet variety of dried khakan fruit.[173] Both pulp and hulls were first removed in a special sheller to leave kernels which were mostly yellow in colour, but did carry a small proportion of green kernels. The latter yielded more oil on ghani pressing than did yellow kernels. The yield of 37 to 43 per cent oil from the kernels went up to 36 per cent when 8 ml of a commercial surfactant (Teepol 710) was added to the 620 ml of total water employed for the ghani operation. The odour of the oil was also reduced. Another brand of surfactant (Teepol B-300) gave an equally good yield enhancement, but the use of these surfactants meant that the cake could only be used for fertiliser purposes. Surfactant caused the time of ghani crushing to be greatly reduced, from an exceptionally long four hours to two to two-and-a-half hours.

Expeller crushing does not seem to present any difficulties and has traditionally been carried out without decortication.[171] From the ghani experience, hull removal would perhaps improve khakan oil yield to over 50 per cent.

A horizontal screw-press of the plate type has been experimented with to crush khakan seeds.[75] These were first powdered in a foot-operated pounder (dhenki) and the mass tied in a piece of gunny (jute sacking) and cooked for a few minutes in a steam kettle. The packets were placed between the plates of a press operated by two men, and crushed; the oil-cake was broken to pieces, recooked, and pressed again. Crushing took eight hours for 130 kg of seeds, and the yields, though not stated, are claimed to be "greater than in ghanis"; moreover, the latter cannot handle hard seeds like khakan and neem.

F2. PISA SEED

If pisa fruit is kept without depulping, fungus growth is rapid. Pisa trees occur deep in the forests, and the produce has to be carried 30 km or more to tribal dwellings.[175] The pulp has a high moisture content, and a natural drainage of 20 per cent occurs even during the collection period of two weeks. Some air drying is also resorted to.

Traditionally the tribal Adivasis release fat by pounding pisa seeds and then rendering them with boiling water.[175] The fat content of both seeds (48 per cent) and kernels (75 per cent) is high.[176] The oil is used as an illuminant with cotton wicks in small clay receptacles and gives an excellent light,[175] which is not surprising considering the coconut oil-like nature of the fat.

Lacking fibre, neither pisa seeds nor kernels form cake in a ghani; seeds carrying dried pulp simply slip round the pestle and refuse to be pulverised.[171] Ghani-crushing can however be effected if 0.5 to 2.0 kg of either groundnut or castor cake is added to a 6 kg charge of pisa seed.[71c,173,177]

The operation is smooth, but use of a hot taper is helpful; this can take the form of some cotton waste mounted on a stiff piece of wire, dipped either in vegetable or mineral oil, lighted, and occasionally passed over the surface of the mass in the ghani pit to cause the oil to flow.[173] To facilitate free passage of oil, the outlet pipe also can be intermittently heated. The water needed varied from 1 to 2.5 kg; 0.5 kg of boiling water at 90° to 100°C was added at the start, and the rest, also hot, after 15 minutes. A third addition was made only if the oil out-turn was too low. In 20 experiments with water alone added, the oil yield was 60.5 ± 3.5 per cent, and in 16 others in which the commercial surfactant Teepol 710 (2 ml) was added to the water, the yield recorded was 66.1 ± 4.2 per cent. The time of operation was also halved from three hours to one-and-a-half to two hours.[71c,173]

Oil mills crushing pisa kernels commercially in expellers reported oil and cake yields of 47.8 and 45.5 per cent in one, and 51.5 and 40 per cent in the other.[175] Another report stated that 93.2 kg of air-dried pisa berries yielded just 11.4 kg (12 per cent) of crude fat, but the method of extraction was not mentioned.[178]

F3. CHIRANDI SEED

Both the fruit pulp and the kernel of *Litsea glutinosa* contain oil. The fresh fruit has 68 per cent pulp; after drying and decortication, the dried pulp and shell together constitute 39 per cent and the recovered kernels 61 per cent.[145] The kernels have very high contents of oil, 61 to 70 per cent. Because of depulping and dehulling problems, crushing of the whole fruit is recommended. The yields of oil on an expeller are given as 49 per cent from pulp and 60 per cent from kernels.

9.5 Processing Oilseeds with Oils of an Unusual Nature

G1. MAROTI SEED

Seeds of *Hydnocarpus wightiana*, the common Indian species, have long been valuable commercial commodities. Decortication was traditionally carried out with small hammers, but in recent times decorticators of various kinds are in use.[145]

Ghani crushing was traditionally practised. Watt writes of maroti in 1908: "Kernels are separated, dried in the sun, pounded in a mortar and pestle, broken kernels put in a canvas bag and expressed with a fire in a castor oil mill".[51g] Probably what is meant is a horizontal plate screw-press. Currently in Kerala, where the tree grows and seed markets are well established, both power rotary units (of the type used to crush copra in the area) and expellers are employed, and the oil is exported from the state in zinc barrels.[145]

G2. KAMALA SEED

The pods carry three seeds, and are covered with a yellow powder

which was the valued commercial product of the past. The brittle pods can be decorticated with ease by beating, and doubtless also in modern decorticators of several types. The kernels form 60 per cent of the seeds, and carry 30 to 35 per cent oil.[152d]

Cold hydraulic pressing is stated to yield about half the oil present. Any form of heat is taboo.

Kamala seed oil is highly prone to spontaneous polymerisation, and this occurs with great ease even in the seed itself. The conjugated triene structure of its chief component, kamalolenic acid, and the presence of entities in which as many as eight fatty acids are esterified with a single glycerol moiety, have been held responsible for this.[179] Since the preferred use of kamala seed oil is as a surface-coating material, methods have been devised to extract kamala seeds by macerating the ground seeds with two parts of sesame or linseed oil, heating for an hour, and filtering hot.[180] The product was called Friol, after the Forest Research Institute (FRI), Dehra Dun, where the work was conducted, and the too-rapid drying qualities of kamala seed oil were thereby tempered for convenience of formulation. At the Jamnalal Bajaj Central Research Institute in Wardha, ghani crushing of kamala seed in admixture with sesame seed to produce Friol was shown to be feasible. The residual cake can be expelled again by hydraulic or expeller operation.

Because of the very unusual nature of kamala seed oil, normal solvent hexane extracts only about half the oil present, constituting the less complex glycerol esters. Polar solvents like ether or ethyl acetate will bring down all the oil, but benzene is the solvent of choice.[181] Since even isolation of the oil causes practically instant polymerisation, it is necessary to store the oil with at least 10 per cent of benzene left in it. Use of 0.5 to 1 per cent of antioxidants like hydroquinone or α-napthylamine stabilises kamala seed oil against polymerisation without affecting its drying characteristics. Its remarkable drying properties enable the oil to be used to produce decorative wrinkle-finish surface coatings, and as a part component of quick-drying alkyds.

G3. PINARI SEED

The seeds of *Sterculia foetida* carry 26 to 29 per cent of kernels embedded in a pulpy testa constituting 4 to 7 per cent.[152e] The seed coat is brittle, and separates easily from the kernels. In earlier studies the two were simply processed together, even though the fats from each are quite different in character.[174] The kernel carries about 54 per cent of fat with as much as 59 per cent of two cyclopropene fatty acids (p. 305). As a result, the oil polymerises on heating to 250°C with considerable evolution of heat. No processing details are available.

G4. MALKANGUNI SEED

The red aril which embraces the seeds of *Celastrus paniculatus* carries 30 per cent fat, and the seed kernel 52 per cent.[174] Both fats have long been

in medicinal use, and were doubtless obtained domestically by cooking the materials with water. For laboratory studies, extraction with light petroleum has been employed to yield brownish oils of unpleasant taste, which in addition to triglycerides carry formic, acetic, benzoic, furoic and nicotinic acids esterified with sesquiterpene polyhydric alcohols (see pages 192/3).

9.6 Processing Oilseeds from Shrubs

H1. RATANJYOTI CAPSULES AND SEEDS

Resembling castor seeds in appearance, the seeds of *Jatropha curcas* also occur in three-valved capsules, meriting their common Indian name of wild castor.

Decortication of the capsules is effected with wooden mallets,[68] and a stone chakki or a standard decorticator works well to yield approximately 37 per cent hulls and 63 per cent kernels.[182] The latter could be put through an expeller without difficulty to yield 28.5 per cent of oil, against 24.8 per cent when whole seeds were expelled.[182]

H2. GOKHRU FRUITS AND SEEDS

The seeds of *Xanthium strumarium* are enclosed in a tenacious thorny cover which does not dry to a brittle mass, and whose removal is therefore difficult. An early observation was that, of numerous treatments tried, only soaking of the fruit in dilute (2.5 per cent) sulphuric acid for 12 hours, followed by drying for two days, softens the seed coat.[183,184] Thereafter a light pressing between rollers, and winnowing, yields the seeds as a third the weight of the air-dry fruit.

The same principle of acid soaking and sun-drying was followed in a subsequent approach, after which the seed was decorticated in a disc huller with either corrugated wooden or steel discs.[185] The brittle coat was effectively removed and the hulls (70 per cent) and meats were resolved on a shaker-separator followed by winnowing. Normal expelling of the meats yielded 5 per cent oil; from the oilcake (with 13.8 per cent oil), 11 per cent could be solvent extracted.

H3. HURHUR SEED

Called the dog or wild mustard, seeds of *Cleome icosandra*, which are commercial commodities, closely resemble mustard seeds in being small, globular and dark brown in colour. Screening through decks with 1.6, 1.3 and 0.7 mm apertures separated extraneous material, after which the seeds were humidified to 10 per cent moisture, flaked, cooked at 100°C and crushed twice in a standard expeller.[186] Yields of oil were about 18 per cent.

The oilcake had oil 6 to 10 per cent, protein 17.5, crude fibre 41.0 (an exceptionally high figure, suggesting only manurial use), total ash 6.5 and acid-insoluble ash 2.3 per cent[186].

H4. SOMRAJI ACHENES

The fruits of *Vernonia anthelmintica* are really hairy achenes 0.5 cm long with 10 ribs, which carry a bitter resin acid (1 per cent). No processing details are available. The oil obtained in the laboratory by solvent extraction was not bitter.

H5. ARGEMONE SEED

The ubiquitous seeds of *Argemone mexicana* have gained notoriety in India for the unpleasant toxic effects of their oil. The contamination of mustard seeds, which argemone closely resembles, could occur by chance during mustard seed harvesting, since these prickly plants flourish everywhere; moreover the seeds are held absolutely dry in the capsules, which yield a mass of them on simply being tipped over. Deliberate contamination is also not unlikely. Episodes of endemic dropsy and of glaucoma were traced to the presence in mustard and other oils of argemone oil even in very small amounts of 1 per cent (p. 193). If crushing or solvent-extraction of argemone seeds is carried out, this would only be as a clandestine operation.

9.7 Processing Oilseeds from Trees that Yield Other Commercial Products

I 1. AKRA SEED

The seeds of *Calotropis gigantea* and *C. procera* are a byproduct of carding of the silk cotton floss found in the pods. The small black seeds have 27 per cent fat,[152f] and the olive green oil is even obtained by commercial solvent extraction.[65] Processing details are not available.

I 2. SIMUL SEED

A byproduct of the carding of silk cotton found in the pods of *Bombax ceiba* is the seed, smooth, slightly avoid and carrying 22 per cent fat.[152g] No processing details are available. Since the seed is a widely-available raw material, this oilseed has fair potential.

I 3. KAPOK SEED

This well-known silk cotton is from *Ceiba pentandra*, in the floss of which is embedded numerous round black seeds with an oil content of 40 per cent, amenable to expeller operation.[152h] Since the carded kapok floss is a commercial product, the seed should be available for exploitation.

I 4. BAHEDA SEED

The fruits of the belleric myrobalan, *Terminalia belerica*, are collected for tanning, and are currently solvent extracted commercially to yield baheda oil. The fruit itself is eaten fresh by goats, sheep, cattle and monkeys. The seed is 2 to 3 cm in diameter, with a hard kernel that yields

8 to 11 per cent oil.[238A] The kernels are eaten on occasion, but large quantities are said to cause intoxication.[51g]

Of a related species, *Terminalia catappa*, called the Indian almond, a report in 1966 states that the oil is "very similar to almond oil in flavour, odour and specific gravity".[51g] The yield of dry almonds per tree is about 4.5 kg, and 50 per cent oil was obtained by cold expression of the kernels. It is stated that the kernels "are largely eaten as a dessert, and the oil-cake is considered a good food for pigs".

I 5. PALAS SEED

The tree is cultivated in plantations to serve as a host for the lac insect. Each of the flat 6 mm pods, 15 to 20 cm long and 2.5 cm broad, yields on decortication with a wooden mallet one reddish-brown, flat, oval seed, kidney-shaped at the apex.[145,152l] The seeds are commercial commodities, and carry both lipolytic and proteolytic enzymes. The skin is leathery and adherent, and the 17 to 19 per cent of oil present is easily recovered by solvent extraction. Expeller pressing is said to deliver about half this oil.[145]

I 6. TEAK SEED

Teak is the timber of India *par excellence*, but the seeds, potentially estimated at 300,000 tonnes annually, are not exploited except for regeneration. The irregularly-shaped, globose seeds are hard, brown and woody, carried in drupes of similar description. Each seed is 11 mm long and weighs about half a gram, but about 90 per cent of this constitutes shell and another 8 per cent calyx, the kernels thus forming just 2 per cent. In a pilot-plant study of processing, the seeds were cleaned on a 3-deck mechanical siever, dehulled in a disc huller and the kernels isolated rather imperfectly using a shaker separator and cyclone segregation.[187] The soft white kernels turned pink on keeping. The oil was removed by solvent extraction in 40 per cent yield. These unusual kernel characteristics will need to be considered in any commercialisation.

I 7. TAMARIND SEED

The preparation of tamarind pulp for the market involves seed removal, followed by compression of the acidic residue. Some 140,000 tonnes of seed are potentially available.[188] The hard, shiny brown seeds are commercially decorticated by abrasion, after roasting to render the shells brittle. The kernel powder is a starchy material employed as a sizing agent in textile and jute processing, and in the manufacture of gums and adhesives for its high polysaccharide content.

In processing on a pilot plant, tamarind seeds were moistened, and disintegrated in a hammer mill fitted with a perforated screen to hold back hull fragments (30 per cent), and the resultant starchy mass (70 per cent) was flaked and air-dried.[188] Alternatively, the kernels were cooked in a kettle cooker and passed through an expeller to give a cake-like material.

Solvent extraction of the mass yielded the oil in 7 per cent yield, against 7.6 per cent present. Removal of the unsaturated oil (IV 103-118) would prevent browning of the meal, and improve its quality for potential use as a food for humans or cattle.

9.8 Processing Oilseeds from Fruits

J1. MANGO KERNELS

The large stones at the centre of the delicious mango pulp are discarded when the fruit is eaten, and constitute about 15 per cent of the fruit weight.[189] The stones consist of about equal parts of a tough, fibrous outer shell and a soft, smooth, shiny kernel. Historically, the kernels have been an item of human food. To remove the astringency caused by the tannins present (constituting 0.11 per cent), the kernels were traditionally boiled, dried and then ground to flour, or roasted, salted or pickled.[190] It was recognised that the flour kept poorly and had to be eaten when freshly made.[152j] The kernels were also fed to cattle and poultry after shredding.[10f]

Storage of mango stones frequently leads to blackening of the kernels within 48 hours through leaching of the shell tannins inward.[191] Fungus infestation is also often visible. In blackened stones, the extractable fat fell from 11 to 7.5 per cent, and free acidity rose from 10 to 48 per cent. Other studies show a similar rapid increase in fat acidity.[192] Drying in the sun or by mechanical means to a moisture level below 10 per cent is therefore essential for commercial operation.[191] A hand-operated rotary drier for the purpose was described earlier (page 246).[192]

Decortication of the stones with a modified copra cutter has been described elsewhere (page 254). The well-dried kernels can be stored for four months without deterioration. Cooking, expelling and solvent-extraction of the kernels yielded about 11 per cent of fat.[193]

Direct solvent extraction of mango kernels has been a commercial operation in India for the last decade. The kernels are broken up in hammer mills, flaked in corrugated rollers, cooked with open and closed steam, flaked again, and solvent extracted in continuous units at a 10 to 12 per cent moisture level.

J2. THUMBA SEED

The numerous white or brown seeds actually make up 6.2 per cent of the weight of the dried fruit of *Citrullus colocynthis*, the bitter medicinal colocynth. The seeds are small (100 weigh only 2.7 g), the hull: kernel ratio is 60 : 40, and the seeds contain about 21 per cent oil.[194] Expelling is stated to yield about 12 per cent oil.[145] Solvent extraction of thumba seeds is commercially practised in India, about 156 tonnes of oil being thus recovered in 1985-86.[65]

J3. WATERMELON SEED

The numerous seeds of the refreshing watermelon carry about 27 per

cent oil, which has traditionally been used as an illuminant and for cooking.[31b] It was probably obtained domestically by grinding and extraction with water.

Pilot-plant processing operations (OTRI) comprised cleaning (clipper cleaner), disc dehulling after addition of 5 per cent moisture to reduce both hull and kernel breakage, and two passages through the expeller after adding back 10 per cent hulls. This yielded slightly over 22 per cent of oil, leaving 8.7 per cent oil in the cake.[195] Using 20 per cent added hulls gave more oil in the first pressing, but about 1 per cent less total oil after two pressings, and cake of lower protein content, 40.5 per cent, against 47.2 per cent for the cake when only 10 per cent hulls were used. Today watermelon seeds are commercially solvent extracted, probably directly and without decortication.

J4. MUSK MELON SEED

The numerous cream-coloured seeds of the musk melon have long been collected in households, and dried in the sun. The seeds are split in the mouth and the kernels munched. The dried seeds are decorticated by gentle pounding to release the soft inner kernels from the brittle shells. The kernels are used in Indian confectionery for their nutty flavour as substitutes for almond, pistachio and chironji (*Buchanania latifolia*) nuts. Today the seeds are being assembled and dried as commercial commodities.

Modern processing of the seeds, which have 64 per cent kernels with 47 per cent oil, was examined following cleaning on a 3-tier shaker unit.[196] The seeds being thin and long (8 mm), dehulling posed some problems. The flat seed simply slipped through the gaps between smooth or corrugated rolls, and a bar huller caused considerable powdering. Disc hulling was finally adopted, with the gap adjusted to minimise fines formation. Expeller crushing of meats alone yielded 19 per cent oil; the yield was the same when 15 per cent hulls were added to the meats before pressing, but the presence of hulls darkened the oil colour. Other modern processing studies of musk melon seeds have been reported.[114A]

J5. LIME SEED

The seeds of the acid lime, *Citrus aurantifolia*, form about 1 per cent of the fruit weight, and resemble those of other citrus fruits, but are smaller in size.[197] After cleaning, the seeds are dehulled in a disc huller, followed by sieving and air-classification. However in practice the yield of 29 per cent oil was not materially altered when either whole seeds with 35 per cent hulls, or kernels with just 5 per cent hulls, were expeller pressed.[197] The whole seed oilcake, at a residual 10 per cent oil level, had 30 per cent protein, 22 per cent crude fibre and 8 per cent ash, but a dehulled oilcake had considerably more protein (45 per cent), considerably less crude fibre (8 per cent) and more total ash (10 per cent). Thus dehul-

ling would greatly improve cake quality, though the presence in it of bitter principles would only make for fertiliser use.

J6. SWEET ORANGE SEED

The loose-skinned mandarin orange of India, *Citrus reticulata*, is a very popular table fruit that is also commercially processed for juice. The pips have a hull-kernel ratio of 27 : 73, and they were initially cleaned on a shaker screen, disc-hulled and then separated by shaker-separation and cyclone blowing.[198] The pear-like shape of the seed, and the nature and adhesion of the coating, made for easy dehulling, and the green kernels on cooking, flaking between smooth rolls and expelling (with 5 per cent hulls added back) yielded 21 per cent of oil.

J7. PAPAYA SEED

Though a vastly popular fruit that is very widely available all the year round, the ripe papaya is mostly consumed domestically and hardly used in commercial products. On the other hand, the raw papaya is employed as a source of commercial papain, and the seeds are green, immature and possibly low in oil. The ripe fruit carries hundreds of small black seeds strongly resembling pepper corns, and indeed used as their adulterant.

The seed is hard and has a cress-like odour attributed to the presence of benzyl thiocyanate derived from its glucosinolate precursor. Solvent extraction yields 25 per cent of fat in the laboratory.[199] No technological processing details have been published in India, nor does commercial processing appear to be in vogue.

J8. SITAPHAL SEED

The sitaphal, though probably an import from South America after the discovery of the New World and the colonisation of India by the British, is now ubiquitous. Each fruit contains nearly 50 seeds. which constitute almost a third of its weight. There is some industrial utilisation of the pulp in drinks, fermented liquors and icecreams, but the bulk is consumed domestically. The quantity of seed is estimated at 400,000 tonnes, which would yield 50,000 tonnes of fatty oil.[200]

The special markets, called sitaphal mandis, where the fruit is vended during the winter season, are thickly strewn with shiny black seeds about 1.5 to 2 cm long, discarded from fruit consumed on the spot. Collection of these seeds showed that the operation was feasible, and they were upgraded by sieving, floatation in water, winnowing and final hand-picking.[200,201]

In another technological study, seeds were similarly collected from local fruit markets.[202] The hard coat, constituting 30 per cent, could be easily separated in a steel disc decorticator, followed by shaker and cyclone separation. The kernels (70 per cent, 36 per cent oil) were flaked between smooth rolls and solvent extracted without difficulty. In another study, deoiled, dehulled sitaphal seed cake was obtained by light petroleum

extraction; the toxic principle was stated to pass wholly into the oil, but no animal experimentation was quoted in support.[203,204]

J9. SAPOTA SEED

Like the sitaphal, the sapota is also a New World introduction which is now ubiquitous in India. Each fruit carries three seeds set loosely in the pulp, about 3 cm long, flat, and with a pronounced white hilum along the edge. Sapota fruits are consumed directly, without as yet any commercial processing; should the latter come into being, the seed would become available in factories.

The kernels constitute 50 per cent of the seed and carry 20 per cent of an oil of IV 60.[157k] No proceesing details have been worked out in India.

J10. GRAPE SEED

Fair quantities of both fruit juice and jam from blue grapes, and of both red and white wines by fermentation, are now produced in India. This should yield grape seeds for possible exploitation. The seeds of various varieties carry 6 to 20 per cent oil, the figure being higher in white grapes than in blue.[152l] Decorticating and expeller pressing are stated to yield 10 to 15 per cent of oil, cold pressing yielding a 'sweet' oil and hot pressing a brown and bitter product.[152l] The oil (IV 134) resembles cottonseed oil in composition.

Processing of grape seeds in India has not been reported.

J11. KAPITTHA SEED

The acidic pulp of the wood apple is studded with small hard seeds (30 mg in weight) which look like those of the guava, and make up 6 per cent of the dry weight of the fruit.[205] These were isolated by agitating the fruit pulp repeatedly with hot water and straining, followed by drying. Solvent extraction of the whole ground seeds, averaging 7 mm in length, 4 mm in breadth and 2.5 mm in thickness, yielded 34 per cent of oil.

9.9 Processing Oilseeds from Vegetables

K1. AMBADI SEED

Known in the New World as mesta or kenaf, the ambadi in India is valued in cooking for its acidic calyces as well as its mildly acidic leaves and stems.

The seeds have an odd tetrahedral shape (Plate 24), and escaped uncut in the usual dehuller; they could however be dehulled in a Bauer stone mill fitted with emery discs, followed by shaker-screen and cyclone separation of the pink kernels (85 per cent).[206] The seed had 19 per cent oil; 11 per cent could be recovered by expelling whole seed, while processing the meats alone yielded 1 per cent more oil.

K2. OKRA SEED

The bhendi is a favourite Indian vegetable eaten fresh and tender. The seeds are sometimes removed and roasted for use as a coffee substitute.[152m] They carry 16.8 per cent fat, 19 per cent protein and 21 per cent crude fibre.

Expelling of whole seed is stated to give a low yield of oil.[152m] Solvent extraction yielded a bright yellow oil with a greenish tinge which was easily refined and bleached.

K3. TOMATO SEED

Growing manufacture of tomato ketchup, sauce, puree and pickles in the country would yield as a byproduct the seeds, which constitute about 0.5 per cent. Cannery discards contain 60 per cent of seeds that can be recovered by floatation.[168b]

In pilot-plant processing, tomato seeds were cleaned, flaked between smooth rolls and solvent extracted to yield 21.2 per cent of oil out of the 25.2 per cent present, because flaking was not complete.[207] In another study, solvent extraction yielded 31 per cent of a yellow oil.[168b]

K4. CHILLI SEED

Seeds are removed for many reasons (p. 120) from dried red chillis before the latter are ground to chilli powder, and are thus potentially available for processing in a quantity that has been estimated at 270,000 tonnes. The oil content is 26.3 per cent.[208A]

In a development study, the small, flat, cream-coloured seeds were first cleaned, humidified with 15 per cent moisture, finely flaked, and then cooked.[208] Expeller crushing yielded 17 per cent oil, which was considerably higher than the values obtained (percentages in parentheses) by crushing seeds directly (3 per cent), as powdered seeds (12 per cent), as powdered seeds with added molasses (11 per cent), and as coarsely-flaked kernels (11 per cent). Thus properly-processed whole seeds yielded the most oil on expelling, even though the hull:kernel ratio was 22 : 78.

CHAPTER 10

The Nature and Upgrading of Unusual Indian Oils

The staple oils of India comprise the historical materials of group A (sesame, cottonseed, rape-mustard, coconut, linseed, castor, niger and safflower), as well as the more recent introductions of Group B (groundnut, soybean, sunflower and oil palm). Being fairly well-known materials, their nature and upgrading will not be considered in this chapter. The less-known oils of India will be reviewed, in respect of fatty acid composition and upgrading, under three categories.

In the first category are those oils which are amenable to normal refining and bleaching procedures, and which again will be divided into two sub-heads. One consists of the oils of Group C (derived from the by-products of cultivated crops), some of which are edible, while others are not. The other sub-group includes oils that are edible, and this selection cuts across the classification of oilseeds (from Group D to Group J) made on other grounds.

The second category consists of oils which also cut across alphabetical groupings. These oils carry lipid associates of unusual kinds, and thus have need of special refining methods; moreover, even after upgrading, the edibility of these oils is at least questionable. These special refining techniques are first generally reviewed, followed by consideration of each oil individually.

Into the third category fall oils of industrial utility that enter surface coating or soaps or medicine, which may or may not be upgraded before use.

10.1 Oils Requiring Normal Refining and Bleaching

A. Oils of Group C

The nine oils which together constitute Group C are shown in Table 13.

C1. RICEBRAN OIL

Ricebran oil of high acidity is an excellent raw material for soap-

Table 13. Oils derived from processing the byproducts of cultivated crops (Group C)[a]

Oil	IV	NS %	Fatty acids 16:0	18:0	18:1	18:2	Others	Preferred use
C1. Ricebran[290]	101	3-6	18	2	42	34	18:3 0-1 20:0 3	Edible, soap
C2. Tapioca seed[128,291]	115	1.0	11	5	25	51	Lower satd. 7	Edible, soap
C3. Maize germ[283b,298a]	125	2	10	3	31	56		Edible
C4. Tobacco seed [293,294,295]	140	2	8	9	10	71		Surface coatings
C5. Rubber seed[294,296]	138	0.8	9	9	19	38	18:3 23	Surface coatings
C6. Turg[216,292,297]	170	1.2		6	18	11	18:3 conj. 65	Surface coatings
C7. Jute seed[283c,298]	121	2 2	16	4	13	62		Edible
C8. Spent coffee[299,300]	91	6-13	30	8	9	46	Higher satd. 5	Unsap. 12%, edibility doubtful. In soap after hydrogenation
C9. Tea seed[218,283c,301]	92	2.2	15	—	58	23		Edible

[a]References given for individual oils are found in the general reference list to Part C (p. 346f).

making, both as such and after hydrogenation to a hard oil. Its consequent high economic value is a deterrent to the production of low-acid oil for edible use. A novel approach to getting a neutral oil from the high acid product has been to re-esterify the oil, after adding some glycerol, at 190° to 200°C in the presence of a catalyst: the free acidity was reduced from 64.7 to just 1 per cent.[209]

Processing problems concern the occurrence in ricebran oil of high levels of free acidity, and the presence of 1 to 5 per cent of wax, of green colour bodies, and occasionally of a red hue deriving from iron soaps. The presence of wax raises considerably the loss of oil during alkali neutralisation, by as much as 11 per cent for an oil with free acidity 11 per cent.[210] It also raises the content of unsaponifiable matter in the refined oil above the legal health limit of 3.5 per cent prescribed in India, and imparts to the oil a hazy appearance. The simplest procedure for the removal of some wax is to allow the oil to stand for a few days, and decant or centrifuge it away from deposited wax. High-speed centrifugation can also compact and remove wax from the oil. The extracted miscella of oil in solvent, if chilled, will also precipitate wax. Commercial dewaxing is not as thorough as is desirable. Uses for the hard non-tacky wax, which has a softening point of 70°C, have also yet to develop.

Degumming is the first stage of refining, and is generally effected with 3 to 5 per cent water containing either 0.1 to 0.2 per cent phosphoric acid, or 1 to 4 per cent of citric or oxalic acids, at about 50° to 70°C with vigorous agitation for 20 to 30 minutes followed by careful centrifugation. Degumming and dewaxing can be combined by adding water containing a surfactant like sodium lauryl sulphate at a low temperature of 8°C, and holding for four hours before centrifugation.

Reducing free acidity by batch alkali neutralisation is generally practised only when the free acidity does not exceed 6 per cent. Thus an integrated process for an oil of FFA 4.2 per cent led to a loss totalling 20.2 per cent in all the steps of degumming, alkali refining, bleaching, dewaxing (8° to 10°C, 100 rpm, seven hours) and deodorisation.[211] Strong alkali lyes (20° to 26° Bé) are employed with an alkali excess of 60 to 100 per cent.[89] The light and fluffy soapstock tends to entrain some oil, and centrifugal separation of soapstock, or the use of refining additives like molasses and sodium metasilicate (1 to 3 per cent), have been recommended.[210] By careful temperature adjustment, gums need not be separated after degumming with phosphoric acid, but can be followed by immediate alkali neutralisation. Addition of a hydrotrope like isopropyl alcohol reduces refining losses by 10 to 20 per cent. Even ricebran oils of very high free acidity (49 per cent) have yielded neutral oils in good yields (40 per cent) by adding 50 per cent isopropanol containing 10 per cent excess alkali to the hexane miscella (5 vols).[212]

Continuous alkali refining can be effected at ambient temperature by allowing five to 15 minutes contact time followed by heating to 70° to 80°C to effect the soap break before contrifugation, or with a contact time

of only a few seconds at 80° to 90°C.[89] Continuous miscella refining using alkali is most frequently effected using isopropanol as a second phase to take up soap, especially where the free acidity is high.

Physical refining involves preliminary degumming of the oil followed by vacuum distillation of free fatty acids to a low residual level. The glycerides are then amenable to normal alkali refining and bleaching.

Re-esterification using 30 to 50 per cent excess free glycerol (on the theoretical required to combine with the free fatty acids) for two hours at 180° to 200°C at 5 mm pressure under nitrogen, either without catalysts or in the presence of 0.2 per cent of stannous chloride or *p*-toluenesulphonic acid reduced the free acidity to 2 to 4 per cent from initial 15 to 30 per cent levels. The percentage monoglyceride decreased from 1.75 to 1.33, and the diglyceride increased from 3.23 to 5.38. The re-esterified oils were amenable to normal alkali-refining and bleaching.[212A]

The greenish colour of raw ricebran oil persists in the alkali-refined material. Conventional bleaching with acidic earth and active carbons (9:1) requires a high quantity (2 to 4 per cent) of the bleaching material and a high bleaching temperature (90° to 120°C). Chemical bleaching includes treatment of the oil with oxalic, citric, tartaric or malic acids, followed by earth-carbon bleaching.[213] Chemical bleaching of any sort is not permitted on oils meant for edible use in India.

High-acid ricebran oil is valued as a soap-making material both as such (as a soft oil) and after hydrogenation (as a hard fat). Washing such oil with sodium silicate solution is practised in certain Indian factories to remove as a compact mass various entities (gums, waxes, colouring matters, iron soaps, etc.) which otherwise act as catalyst poisons during hydrogenation of the oil.[212] Another procedure is to stir the oil with 0.1 per cent of dodecylbenzene suphonic acid at ambient temperature for an hour, and then add 0.1 per cent phosphoric acid (as a 33 per cent aqueous solution) with stirring at 70°C, followed by settling and washing.[214]

Refined and bleached ricebran oil made from raw material of low acidity is an excellent edible oil (IV 101, with oleic 42, linoleic 34, linolenic Trace per cent). Careful studies have shown the exceptional ability of ricebran oil to lower both serum cholesterol and triglyceride levels in human subjects, the factor responsible being a component of the unsaponifiable matter,[254a] probably cycloartenol.[213A]

C2. TAPIOCA SEED OIL

The hydraulic-pressed oil had a free acidity of 2 per cent, and could be easily refined and bleached by normal procedures. The refining loss was 6.5 per cent, and the oil was light in colour. Potato chips fried in the oil were crisp and tasty.[128] The oil has IV 115, with oleic 25 and linoleic 51 per cent.

C3. MAIZE GERM OIL

Commercial refining and bleaching of the solvent-extracted oil yields a well-known edible material of IV 112, with oleic 46 and linoleic 42 per cent. Use of refining additives was found to be highly beneficial in reducing oil loss.[214A]

C4. TOBACCO SEED OIL

Solvent-extracted tobacco seed oil can be refined and bleached in normal ways. Addition of an additive, tetrasodium pyrophosphate, during alkali-refining was found to reduce the refining loss by 30 per cent.[130] Though edible, tobacco seed oil is not permitted for such use in India through deference to the sentiments of the Sikh community who abjure tobacco products. The oil carries 71 per cent linoleic and 1 per cent linolenic acid,[214,215] and if available, would be in demand for surface coatings.

C5. RUBBER SEED OIL

The oil produced by expelling would only need clarification or bleaching for use in surface coatings, for which the IV of 140 and 71 per cent content of linoleic acid makes it very suitable. Solvent-extracted rubber seed oil is known to be hazy through the presence of a fine suspension of particles, perhaps of the nature of rubber, which are coagulable with acetone.

C6. TUNG SEED OIL

Tung oil is of course mainly of value to the surface-coating industry for its rapid drying properties. The IV of Indian tung oil from *Aleurites fordii* is 170, lower than for the Chinese variety, and so is the α-elaeostearic acid content of 65 per cent against the usual 75 to 85 per cent.[215] More of the *Aleurites montana* species is raised in India. The oil from this has a composition identical with that of Indian *A. fordii*.[216] The demand for tung oil in India has been estimated at 4000 tonnes,[134] but the extent of production is not known, and is perhaps erratic.

C7. JUTE SEED OIL

Raw jute seed oil is stated to be bitter in taste, but odourless.[136] Refining and bleaching were normal, with refining factors of 3.5 to 4.5, and a light colour in the final products (5 to 7 Y, 0.6 R, 2.54-cm cell). Washing with aqueous citric acid removed the bitter taste.

The IV of the oil is 121 and the content of unsaponifiables 2.2 per cent. With 62 per cent linoleic and 13 per cent oleic acid, the oil could be turned to use either in surface coatings or as food. Snacks deep-fried in the refined and bleached oil found ready acceptance.[136]

C8. SPENT COFFEE GROUNDS OIL

The chocolate-brown oil obtained by solvent extraction of spent coffee grounds, left after preparation of 'instant' coffee powder, was found to

carry a high content of unsaponifiables, from 9 to 13.2 per cent.[217] This could be a deterrent to edible use. The IV of 91, with 29 per cent palmitic, 19 per cent oleic and 44 per cent linoleic acid, suggests alternative use for soap-making after hydrogenation. The refining and bleaching characteristics of the oil have not been reported in India.

C9. TEA SEED OIL

Raw tea seed oil expelled from kernels containing 5 per cent hulls was found to have a slight but hardly discernible bitter taste. This was removed by standard alkali refining and bleaching.[138] Indian tea seed oil has a high content of oleic acid (57 per cent) and a moderate linoleic acid level (24 per cent), with IV 92 and 2.2 per cent of unsaponifiable matter.[218] The oil carries 0.2 to 0.3 per cent of theasin;[138] this is the compound responsible for the characteristic Fitelson colour reaction of teaseed oil which serves to determine its presence as an adulterant of olive oil.

B. Edible Hard Vegetable Fats

The oils that will be discussed here are listed in Table 14, which sets out their IV, percentage unsaponifiables, fatty acid composition and oil type by reference to well-known oils.

E1. MAHUA FAT

Mahua fat is amenable to normal refining and bleaching. As with all the high-melting fats now being considered, the miscella refining of mahua fat in solvent medium has many advantages. As is usual with these fats, low-acid products are refined and high-acid ones used for soap-making.

Alcoholic alkali yielded a refining loss 1.1 to 1.3 times the free acidity.[219] Addition of 1 per cent of phosphoric acid drop-wise to the fat at 90°C with vigorous stirring coagulated gummy materials and yielded fat of very low colour, the soaps from which were not prone to rancidity.[220] Mahua fat of high acidity was effectively miscella-refined on a pilot-plant scale with alcoholic alkali.[221]

The widespread crushing of mahua kernels in chappas (Section 8.1) yielded fat that was used in the home even in the unrefined state, and refined mahua fat has generally been considered as edible. Though the nutritional quality is normal in rat feeding studies, the occurrence of male sterility, which was reversible, has been noted.[355a] Its fatty acid composition (Table 10) justifies its long use as a hardening component in soap. Its more recent outlet as a base for formulation of cocoa butter substitutes will be considered shortly (p. 292).

E2. SAL FAT

The pigments of sal fat are chlorophyll a, chlorophyll b, protochlorophylls and xanthophylls,[222] and acidic bleaching is indicated. Pretreatment prior to alkali-refining with 5 to 7.5 per cent of 15 per cent citric acid, or with 3 to 5 per cent of sulphuric acid at 60° to 65°C for 30 minutes, or

Table 14. Oils amenable to normal refining-bleaching, and also edibles[a]

Code		Name of oil	IV	NS %	Fatty acids 16:0	18:0	18:1	18:2	Others	Oil type
1		2	3		5	6	7	8	9	10
E	1	Mahua[220,222,302]	58	2.0	25	23	37	14		Cocoa butter
	2	[b]Sal[221a,283e,303,304]	38	2.5	4	47	44	0.4	Epoxy, hydroxy 0-3, 20:0 3	do
	3	[b]Dhupa[222,283e,305]	40	1.5	12	42	42	2		do
	4	[b]Kokum[272,306]	43	0.2	4	65	30	1		do
	5	[b]Tamal[307]	48		4	44	46	3		do
	6	[b]Phulwara[283f,303]	42	0.8	65	2	29	4		do
H	1	Ratanjyoti[225A,283b,308]	101	1.0	16	10	41	32		Groundnut
	2	Gokhru[309]	136	1.2	10	4	18	68		Safflower
	3	[c]Hurhur[188,236]	130	2.0	11	5	14	69		do
I	1	Akra[237]	55		14	19	63	3		Groundnut
	4	[c]Baheda[238,238A]	89	0.5	35	8	24	31		Equal SOL[d]
	6	Teak seed[300,310]	122	1.5	13	8	21	56		Cottonseed
	7	Tamarind[188]	103	12.1	9	4	20	55	18:3 3, Higher satd 14	do
J	1	Mango kernel[189,222,231h,271,311]	32-61	0.4	6-18	24-49	33-53	0-13		Cocoa butter
	2	Thumba[283f,312]	122	1.4	11		37	52		Cottonseed
	3	Watermelon[188c,313,314A]	118	1.2	11	10	15	63		do
	4	Muskmelon[188d,314]	128	0.9	9	—	25	65		do

J	5	Lime[300,315]	115	0.5	30	3	22	34	18:3	11	Equal SOL[d]
	6	Sweet orange[300,315]	110	1.5	20	5	33	39	18:3	2	do
K	2	Okra[242,283g,288,289b]	97	1.0	30	5	29	34	Cyclopropane	2	Equal SOL[d]
	3	Tomato[288h,316b]	114	1.2	7	6	35	50			Cottonseed
	4	Chilli[306,308b,316b]	136	1.9	16	3	8	73			Safflower

[a]References given for individual oils are found in the general reference list to Part C
[b]Edibility established through usage
[c]Edibility established through toxicological testing
[d]Equal proportions of saturated, oleic and linoleic acids

with 1 per cent of 10 per cent aqueous phosphoric acid for 10 minutes followed by 2 per cent of 10 per cent sodium chlorite at 90°C for 30 minutes, all conduce to subsequent refining and bleaching.[223] A high proportion of activated earth (3 per cent) and activated carbon (2 per cent) at a high temperature (120°C) after normal alkali refining achieves satisfactory bleaching, and is in commercial use in India, chemical bleaching not being permitted for edible fats. Even exposure to sunlight of the fat in thin layers, or of the hexane miscella, achieves bleaching; the latter procedure does not result in peroxide build-up as does the former.[224]

Miscella refining of a sal fat of high free acidity (22 per cent) in a concentration of 42 to 50 per cent, using 12° Bé caustic and 2 per cent (as dry caustic) excess, resulted in a refining loss of 40 per cent (refining factor about 2) and yielded a fat that could be easily bleached with 2.2 per cent of an earth-carbon mixture at 80°C.[164] Simply dissolving sal fat in hexane, and countercurrent washing with alkali in aqueous methanol or propanol, results in refining factors that are only 10 to 20 per cent above the theoretical.[212]

The edibility of sal fat is based on a hoary tradition of usage by tribal peoples living in forest areas, and by modern investigations which established normal nutritional behaviour and toxicological safety at a 10 per cent level in the diet of rats.[225] Only the digestibility at 63 per cent was rather low: this was only to be be expected from the high stearic acid content, and is indeed similar to the figure for cocoa butter. By law in India, sal fat can be used in confectionery, and also to a maximum of 10 per cent in the edible hydrogenated oil product, vanaspati, but not for unrestricted general edible use. Another limitation is that the content of epoxy and hydroxy fatty acids taken together should not exceed 3 per cent.

These fatty acids apparently arise during storage of sal seed by the action of oxygenases. Neither moulds nor insect infestation appear to contribute to epoxy acid formation.[158a] Controlled studies showed a rise of epoxy acid to a maximum level of about 2.8 per cent, after which it declined, apparently passing on to the dihydroxy acid by hydration.[226] Dewinging by burning destroys the oxygenating enzyme, but if mechanical decortication is practised, drying must precede storage if fat quality is to maintained.

The presence of oxygenated acids and of partial glycerides affects the utility of sal fats in the manufacture of chocolates. These can be removed by holding sal fat at 35°C for six hours with occasional stirring, filtering the solids (12 per cent), and washing them free of normal glycerides with light petroleum to yield 2 per cent of oxygenated glycerides; the beneficiated sal fat has improved solidification properties.[226A] Absorption of these from sal fat in hexane solution on a special cogelled alumina absorbent has led to a patented process for their removal, which is in commercial use.[227] The columns used are freed of absorbed material by washing with a more polar solvent.

Sal fat contains 3-ketotriterpenes which form 15 per cent of the unsaponifiable matter, and consists of β-amyrenone, cycloartenone and lupenone.[228] Later these and other 3-ketotriterpenes were found in different percentages in several other vegetable butters, though not in mahua fat:[229]

	Sal	Kokum	Phulwara	Mangokernel
α-Amyrenone	—	13	—	24
β-Amyrenone	Present	21	—	28
Lupenone	Present	—	100	24
Cycloartenone	Present	42	—	24
24-Methylene cycloartenone	—	24	—	—
Total, as % unsap. matter	15	12	7	4

Since cocoa butter does not contain these triterpenes, their occurrence could serve to determine the presence of these fats.

High-acid sal fats find use in soaps, and low-acid materials after upgrading for edible purposes. The use of sal fat in the preparation of cocoa butter extenders will be considered below (p. 292).

E3. DHUPA FAT

The pale greenish-yellow dhupa fat is easily refined and bleached to excellent whiteness. Free fatty acidity can be very high (even 24 per cent) because of adverse procurement practices, and such fat has long been used for soap-making in the state of Karnataka where the tree grows in abundance.

E4. KOKUM FAT

The exceptionally high melting point, 40° to 43°C, of kokum fat would make it particularly well suited to miscella refining. Even conventional refining and bleaching yield a product of near white colour.

E5. TAMAL FAT

The fat of *Garcinia morella* is not an industrial commodity, and refining and bleaching data are not available.

E6. PHULWARA FAT

Refining and bleaching data on the fat of *Diploknema butyraceae* are not available.

J1. MANGOKERNEL FAT

The free acidity of mangokernel fat can lie between 3 and 6. The pale yellow or cream-coloured fat is very easily refined using 16° Bé lye to a yellow colour, followed by treatment with 2.2 per cent of activated earth and carbon (10 : 1) to give a fat of white hue (0.4 Y, Nil R, 0.635-cm cell).[230] However a fat of free acidity 5.0 showed a refining loss of 18 per cent.[193] The very high refining factor of 3.6 seems to be connected with

the high melting point, and miscella refining is indicated. Mangokernel fat is commercially refined and bleached to a valuable export material.

C. USE OF HARD VEGETABLE FATS AS COCOA BUTTER EQUIVALENTS

The unique qualities of cocoa butter are its brittle nature, sharp melting at 34°C on the tongue without leaving a feeling of greasiness, and a slight contraction of 2 per cent on solidification which enables chocolates made with it to be easily tapped out from a mould. These characteristics in turn stem from the presence in it of the fatty acids palmitic 25, stearic 35, oleic 35 and linoleic 2 to 3 per cent. Just as important is the assembly of these fatty acids, to the extent of nearly 80 per cent, as the symmetrical oleins POP 12, POSt 35 and StOSt 25 per cent. Attempts to make cocoa butter equivalents or CBE from Indian vegetable hard fats depend on the kind and proportion of symmetrical oleins that can be obtained from each of them.

Mahua fat has StOSt 6, POSt 13 and POP 7, total 26 per cent, and one crystallisation from acetone at 0° to 12°C will yield the fraction required.[231a] Because it is cheaper to obtain such a CBE from palm oil, mahua fat is less favoured for the purpose.

Sal fat has StOSt 40-43, POSt 8, ArOSt 10-14 (Ar=Arachidic), total 69 per cent, which explains its present demand. Commercial crystallisation from acetone at 7°C yields a fraction constituting 76 to 78 per cent which is substantially a symmetrical mono-olein, melting sharply at 39°C and compatible with cocoa butter in all proportions.[232] Another commercial approach is to slightly hydrogenate sal fat so as not to raise its content of SSS glycerides beyond 2 per cent, followed by tempering for three to four days to 20° to 35°C and pressing out a liquid fraction at 200 to 700 psig and 20° to 35°C to yield the hard residual CBE.[233] Alternatively the hydrogenated fat is kept at 37°C for 48 hours, and the 15 per cent of high-melting glycerides filtered off to yield the desired CBE as a liquid fraction.[234] The presence of high levels of StOSt, and of arachidic (20:0) acid as ArOSt makes for a higher melting fat (39°C), which is an advantage in chocolates manufactured for use in hot climates, both as regards softening, and bloom through fat migration. An 85 : 15 blend of sal stearin and mahua stearin is also a very satisfactory CBE.[235]

Dhupa fat has 47 per cent of StOSt and 17 per cent of POSt, a mix of which is afforded in a single crystallisation from acetone.

Kokum has so excellent a natural glyceride pattern that it can even be used as such, without segregation, as a CBE. StOSt makes up 78 per cent and POSt 5 per cent, with POP in traces. In fact a 30:70 blend of kokum insolubles and mahua insolubles resembles cocoa butter very closely, both in theory and performance.[234]

Phulwara fat has POP 53, POSt 8 and StOSt in small amounts, so the stearin, though not substantial in quantity, is too rich in POP for satisfactory performance, and needs stearic-glyceride support.[231b]

Mangokernel fat has some inherent difficulties in CBE use. The fatty acid composition varies rather widely (Table 14), palmitic from 6 to 18 per cent, stearic from 24 to 49, oleic from 33 to 53, and linoleic from Nil to 13 per cent, while the overall IV varies widely from 32 to 61.[223] This means an even wider variation in the content of symmetrical olein glycerides. However, the best isolation plan appears to be to discard the first acetone-insoluble fraction (at 20° to 26°C), and then crystallise out a more appropriate mass at about 5° to 10°C.[235] Alkali-catalysed interesterification of mangokernel fat with methyl palmitate for enrichment, followed by double fractionation from acetone, yielded a fat which had almost exactly equal proportions of palmitic, stearic and oleic acids; however the CBE characteristics turned out to be poor.[231h]

Tamal fat has 46 per cent of mostly StOSt. It is therefore an excellent source of this component, even if not in itself, or after fractionation, a true CBE.[231c]

Indeed in practice, blending of appropriate glycerides is clearly the preferred approach. Sal or tamal fat would yield the StOSt component, a palm oil mid-fraction the POP, and mahua fat the POSt balanced with both POP and StOSt. The methodology for evaluating CBE performance against cocoa butter itself[234A] consists *inter alia* of three tests (Fig. 30). Cooling or solidification curves show the temperature fluctuation with time as the fat cools from say 30° to 20°C; cocoa butter shows a characteristic rise, following a maximum value of 21°C that occurs after about 25 minutes. Another test measures the content of solids at various temperatures from say 30° to 38°C, cocoa butter for example showing 83.5 per cent solids at 25°C, 61.9 per cent at 30°C, 16.9 per cent at 33°C and none

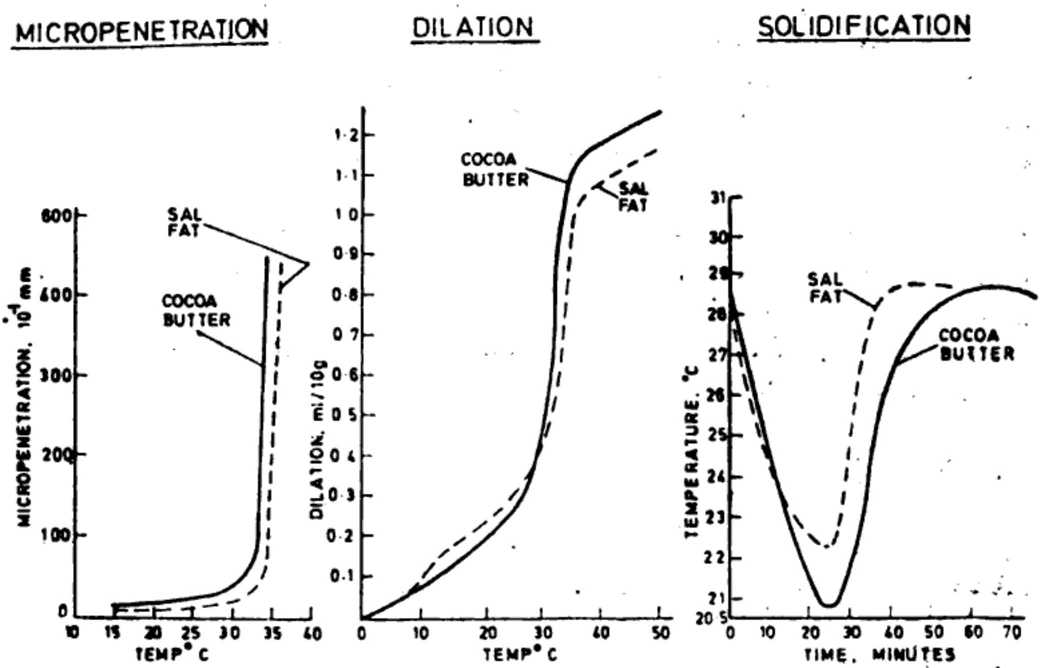

Fig. 30. Performance tests for cocoa butter and sal fat (Source: Adapted from Bhambhani, Shitole and Kane[234A])

at all at 36°C. Both dilation and micropenetration tests reflect the solid fat index.

D. Other Edible Fats

The next group of oils whose upgrading to edible quality is to be considered are those also shown in Table 14 (page 288-9), drawn from the H, I, J and K groups.

H1. RATANJYOTI OIL

The dark yellow but bland expeller oil from the kernels of *Jatropha curcas* is easily refined to a colour of 2.8 units (Y plus 10 R, 2.54-cm cell).[167] The IV of 100, 40 per cent content of oleic and 32 per cent of linoleic acid is broadly of the groundnut type. Mature seeds, and seeds harvested in summer, have relatively higher linoleic acid contents.[235a] The unsaponifiable matter (1.6 per cent) inhibits soil nitrification, so caution in edible use is called for.[235a]

H2. GOKHRU OIL

The expeller oil of *Xanthium strumarium* seed is brown, and the solvent oil dark green, while the refining factor for oils of free acidity 1-2 was 4.5.[185] The oil was easily refined and bleached to a colour of 13Y, IR on a 2.54-cm cell. With IV 136, 18 per cent oleic and 68 per cent linoleic acid, the oil resembles safflower oil.

H3. HURHUR OIL

This oil appears to be very similar chemically to gokhru oil: IV 130, oleic 14 per cent, linoleic acid 69 per cent. However, a persistent hydroxyl value of 11.2, and the failure of about 1.5 per cent of the methyl esters to elute from either silicone or polyester columns, suggests the occurrence of oxygenated acids in small amounts.[186] The clear, faintly green oil could be easily refined with a 100 per cent excess of 20° Bé lye to reduce the chlorophyll level from 15 ppm to just 0.65 ppm, and further bleached to remove even this trace and yield an oil of 2.5 Y, 0.2 R (2.54-cm cell). The refining factors were high, being 3 for an oil of 14 per cent free acidity, and 4.1 for one of 4.4 per cent.

The edibility of the oil has been established by systematic nutritional and toxicological examination.[236]

I1. AKRA OIL

This interesting oil, with IV 55 and 66 per cent oleic acid accompanied by only 3 per cent linoleic,[237] is processed commercially,[65] but no details are available. Nor has its edibility been established.

I2. BAHEDA OIL

Forest dwellers have long employed the oil in cooking. The edibility of baheda oil, after laboratory refining, has been established in short-term

studies on rats.[238] It represents a product in which saturated (mostly palmitic), oleic and linoleic acids are at similar levels of about a third each[238A]

I6. TEAK SEED OIL

A cottonseed type oil, with 56 per cent linoleic and 21 per cent oleic acids, of IV 122, teak seed oil though bright red in colour when solvent extracted is easily refined by standard procedures to an oil of light colour (2.4 Y, 1.0 R, 0.635-cm cell) and bland odour. Edibility has not been ascertained.

I7. TAMARIND KERNEL OIL

The solvent oil is of a dark brown colour, because the kernels are so small and difficult to isolate free of shell. The acidity also tends to be high and the unsaponifiable matter constitutes 2 to 4 per cent. The refining factor was large (3.6), but the refined oil bleached easily to a hue of 15 Y, 1.9 R (2.54-cm cell).[188] Since tamarind kernels are roasted and eaten along with the fat, edibility is likely but has not been systematically ascertained. The oil has IV 103 and broadly resembles cottonseed oil, but carries 3 per cent of linolenic acid and 14 per cent of higher saturated acids.

J1. MANGOKERNEL FAT

This has been considered earlier (page 291), along with the vegetable butters of Group E.

J2. THUMBA OIL

Colocynth oil has long been domestically expressed as a pale, brownish-yellow oil with a bitter taste,[239] for use as an illuminant, as a hair oil, and for soap-making. The oil is of the cottonseed type (IV 122, oleic 37, linoleic 52 per cent). On recent examination colocynth seed oil was found to be a material of low free acidity which was easily refined and bleached from a colour of 13 Y, 0.9 R (2.54-cm cell) to one of 6Y, 0.3 R.[240] The oil is now solvent extracted in tonnage.[65] Its edibility has not been examined.

J3. WATERMELON SEED OIL

The crude oil itself has a light colour and low free acidity (1 to 2 per cent). The refining factor was high (about 5), and both the refined and bleached oils were not very different in colour (Y+10R 4 units, 2.54-cm cell) from that of the crude oil (six units).[195] The oil has IV 118 and is of the cottonseed type, with 18 per cent oleic and 55 per cent linoleic acid.[168e,313] Edibility has still to be established.

J4. MUSK MELON SEED OIL

This oil is of naturally low acidity and pale yellow colour, easily refined to a very light hue, and in fact even light enough to be used in the

unrefined state.[196] Oil expelled from whole seed was darker (42 Y, 8.2 R, 2.54-cm cell) than that from kernels (35 Y, 3.2 R) and this carried into the refined oils (4.6 Y, 0.4 R and 2.6 Y, 0.1 R).[196] The kernels have long been in use for confectionery, and are commonly split and eaten at table, so the oil is likely to be edible. Foods fried in the oil were readily accepted by consumers. It is of the cottonseed type (IV 128, oleic 33, linoleic 55 per cent).[168d,314,314A]

J5. LIMESEED OIL

Crude oil expelled from the seed of the lime, *Citrus aurantifolia*, is stated to be brownish-yellow in colour, bitter in taste, and with an odour reminiscent of the fruit. All these are virtually lost on normal alkali-refining and bleaching, the red component in the golden yellow oil being almost unmeasurable (1.5 Y, 0.635-cm cell).[197] The oil has IV 115 and is of the equal saturated-oleic-linoleic type, but carries 11 per cent of linolenic acid. The fatty acid composition suggests probable edibility.

J6. SWEET ORANGE SEED OIL

The oil from the seeds of the Indian sweet mandarin orange, generally classed as *Citrus reticulata*, resembles that of limeseed oil in composition (IV 110, oleic 33, linoleic 39 per cent), but has less linoleic acid (2 per cent). The greenish-yellow oil, with a bitter taste and pleasant odour of oranges, had a low free acidity, and was easily refined and bleached to a bland, light yellow product (1.3 Y, 0.1 R, 2.54-cm cell).[198] Edibility has not been determined, but appears probable.

K2. OKRA SEED OIL

The oil of the Indian bhendi or lady's finger, *Abelmoschus esculentus*, is of the 'equal SOL' type.[288A] The glycerides carry 0.44 per cent of cyclopropene fatty acids[241] and about 2 per cent of cyclopropane fatty acids.[242] The physiological effects of the latter are not known. Data on the refining and bleaching of Indian okra oils are not available.

K3. TOMATO SEED OIL

Use of 20° Bé lye refining, followed by 2.2 per cent of an earth-carbon (1:10) mixture for bleaching, yielded from crude tomato seed oil a product of high quality.[207] The free fatty acid content of the oil was 9 per cent, and the refining loss rather high at 31 per cent. Since tomato seeds are eaten, the oil is likely to be edible, and is of the cottonseed oil type, with an IV of 114.[283h,316A] In another study, unrefined tomato seed oil was fed at 5 and 10 per cent levels to chicks in the first three weeks of growth with the same weight gains as for similar levels of corn oil.[168b] Some 41 per cent of the sterols is stated to consist of cholesterol.[206A]

K4. CHILLI SEED OIL

The raw seed oil of *Capsicum annuum* has the carry-over flavour of

capsaicin, the pungent component of the chilli. For an oil of FFA 3.5, the factor in alkali refining was about 3, and such refining was easily accomplished.[108] The crude oil colour of 13 Y, 1.5 R (0.625-cm cell) was reduced to just 3.2 Y, 0.4 R. The pungency had also been removed, and snacks fried in the oil were perfectly acceptable.[208] Alkali-refined chilli seed oil was without effect on weanling rats, except for a slight fatty infiltration of the liver.[208A] The oil carries 73 per cent linoleic acid, and is of the safflower type.[316,316A]

10.2. Oils with Special Refining Problems, and of Questionable Edibility

A. General Procedures

There are many Indian unconventional oils that are characterised by the presence of associated materials which accompany the oils during expelling or solvent extraction and impart to them a deep colour, an unpleasant odour, or a disagreeable taste. The oils coming under Group D, namely neem, karanja, kusum, nahor, undi and rayana, are all of this description. So are oils from several other groups, all of which are brought together in Table 15.

Before discussing them individually, some general methods of upgrading that have been developed in India to deal with these oils will be reviewed.

Use of alcohol: Ethyl alcohol may be utilised in three ways. The first is for extraction of a comminuted seed, the second for extraction of a portion of an oil, and the third is through the use of alcoholic alkali in place of aqueous alkali for refining.

i) *Seed extraction with alcohol*: Neem seed has been most frequently studied and will serve as an example.[243] The disintegrated kernel is extracted with 92 to 96 per cent aqueous alcohol by continuous percolation, the strength being based on the low solubility of glycerides in this medium. Some 10 to 12 per cent of material is removed, consisting (as percentages) of bitters 2, odorous sulphur compounds 5 to 8, phosphatides 1 to 2 and free fatty acids 2 per cent. The cake still carries 30 per cent of a greenish-yellow oil, since some chlorophylls are not extracted by alcohol. Hexane extraction of the cake removes an oil which is amenable to standard procedures of refining and bleaching.

Alcohol extraction is also stated to be applicable to removing lipid associates from karanja, mahua, phulwara, khakan and gokhru seeds.[243]

ii) *Oil extraction with alcohol*: Again a typical batch extraction of expeller neem oil will be described.[244] A vessel with baffle plates is charged with 150 kg of crude neem oil and 500 kg of 92 per cent ethanol. After stirring for three hours and settling for four to six hours, the top alcoholic layer is withdrawn and fresh alcohol added for another extraction. After five such extractions, residual alcohol-insoluble matter is reduced to about 1 per cent (this stays with the alcohol that is dissolved in the oil). The

Table 15. Oils with refining problems, and of questionable edibility[a]

Oil	IV	NS %	Fatty acids % 16:0	18:0	18:1	18:2	Others	Unusual constituents
D1. Neem[288h, 307]	72	1.5	14	16	56	10	20:0 2	Bitters, odorescent materials
D2. Karanja[290]	88	2.5	13	4	51	24	18:3 7 20:1 10	Furanoflavones, resins, polyphenols
D3. Kusum[281f]	53	1.5	9	2	43	4	20:0 21 20:1 15	Cyanogenic esters
D4. Nahor[300]	83	1.2	14	13	50	19	Lower satd. 3 Higher satd. 3 18:3 2	Coumarins
D5. Undi[317]	71	1.0	18	18	43	14	18:3 2 24:0 3	Phenylcoumarins
D6. Rayana[307]	135	1.6	8	15	11	58	18:3 8	Bitters, resins, odorescent materials
F1. Khakan-Pilu[281g]	10	1.0	9	5	2		12:0 47 14:0 30	Several benzyl derivatives
F2. Pisa:								
Shell oil[271]	62	8	26		54	6	12:0 13	Resin acids
Kernel oil[236]	13	7	1		5		10:0 4 12:0 88 14:0 2	Strong aromatics, resin acids
F3. Chirandi:								
Fruit oil		No details available						Strong essential oil
Kernel oil[280i]	6				2		12:0 96	

I5. Palas[272,280]	85	1.9	21	9	28	26	20:0 6 22:0 6 24:0 4	Flavonoid glycosides
J7. Papaya[190]	68	0.6	17	4	77	1		Benzyl thiourea
J8. Sitaphal[278,316]	83		15	15	46	20	18:1hy 10	Toxic resin
J9. Sapota[316d,320]	60	1.8	14	11	65	2	14:0 9	
J10. Grape[303j,321]	134		8	5	21	66		Bitters

[a]References given for individual oils are found in the general reference list to Part C

alcohol is recovered from both extractive and bulk oil for re-use, and the oil is of good quality, with its acid value reduced from 30.7 to 1-1.5 cent cent.

Alcohol extraction can be carried out in one or more stages. Table 16 shows the batch extraction of a mahua fat (13 per cent free acidity) in one, two and three stages.[245] Multiple extraction with more dilute alcohol gives a higher yield of product of low free acidity than a single extraction with a high alcohol-to-fat ratio, when more neutral fat is dissolved out.

Table 16. Batch deacidification of mahua fat with alcohol[244]

Mahua fat of 13 per cent free acidity; room temperature

Fat: alcohol ratio by wt.	Yield of raffinate %	FFA of raffinate %	FFA of extract %
A. Single-stage extraction with different ratios of fat: alcohol (95%)			
1:1	93.1	8.7	62.0
1:2	88.2	6.3	59.0
1:4	83.5	4.2	54.3
1:10	42.0	1.8	30.0
B. Two-stage extraction with fat: alcohol (95%) ratio of 1:4			
First stage	83.5	4.2	54.3
Second stage	80.2	1.3	19.7
Overall yield of fat at end of second stage, 67%			
C. Three-stage extraction with fat: alcohol (90%) ratio of 1:4			
First stage	83.5	4.0	53.2
Second stage	93.7	3.2	41.3
Third stage	96.6	0.8	20.3
Overall yield of fat at end of third stage, 75%			

Alcohol upgrading of neem, karanja, undi and pisa fats is shown in Table 17. Part of the non-fatty constituents are removed, the free acidity is decreased, and the red colour component is frequently reduced.[246]

iii) *Refining with alcoholic alkali*: In alcohol extraction of oils, free fatty acids are partitioned between the oil and alcohol, but when alcoholic alkali is employed, the fatty acids are converted to soaps which dissolve almost entirely in the alcohol layer. Phase data obtained for a number of alcohol-oil-soap systems using mahua and sesame oils as models showed that oils could be refined using alcoholic alkali with a refining loss only 1.1 to 1.3 times the free fatty acidity.[219] Using a York-Scheibel counter-current column, karanja oil of free fatty acidity 2.6 was refined with 2 vols of 0.206 N alcoholic (90 per cent) alkali to an oil of free acidity below

Table 17. Alcohol treatment of some minor oils[246]
90%; 1:4 (v/v); refluxing, cooling and separating

Characteristics	Neem	Karanja	Undi	Pisa
1. *Untreated oils*				
AV	9.3	5.4	27.6	85.6
IV	77.4	87.2	92.3	17.1
Unsap. %	2.1	4.3	1.3	3.8
Colour (1-cm, Y,R)	11.0, 3.3	18.0, 3.0	9.3, 3.0	—
2. *Raffinate*				
Yield, %	84.1	90.7	81.5	38.0
AV	7.8	3.0	7.1	72.2
IV	59.8	89.2	86.5	5.6
Unsap. %	1.2	3.1	0.5	3.2
Colour (1-cm, Y,R)	10.0, 1.2	14.0, 2.4	6.0, 0.6	Yellowish white
3. *Extract*				
AV	39.8	45.3	157.4	136.8
IV	85.0	61.2	110.0	24.3
Unsap. %	6.9	18.2	5.2	4.6
Colour	Dark brown	Brownish yellow	Dark brown	Dark brown

0.05; this was a considerably better performance than the use of alcohol alone. Moreover, while a number of stages were required to lower the free acidity when alcohol was used, a single stage sufficed with alcoholic alkali.

Table 18 provides a picture of the comparative value of aqueous alkali, alcohol extraction and alcoholic alkali for the upgrading of neem and karanja oils.[246] Alcoholic alkali treatment, apart from general efficiency, is particularly effective in removing the red colour component, indeed to

Table 18. Upgrading of neem and karanja oils by various methods

Type of oil	Neem		Karanja	
	Colour (1-cm) Y, R	AV	Colour (1-cm) Y, R	AV
Raw	15.4, 4.0	12.3	17.1, 2.1	3.9
Refined with aqueous alkali	12.6, 3.4	0.6	15.4, 2.1	0.4
Refined with alcohol	8.2, 1.8	1.4	9.2, 1.3	0.6
Refined with alcoholic alkali	7.0, 0.5	0.5	3.8, 0.1	0.4

such an extent that for both oils subsequent earth-carbon bleaching can be dispensed with.

While alcoholic alkali refining of several minor oils was believed to have been in commercial operation a decade ago, for economic reasons it has now been abandoned in favour of other upgrading procedures, which are described below.

iv) *Use of other alcohols:* The refining of high-acid ricebran oil by washing the hexane miscella with isopropanolic alkali has already been described on p. 284.[212] The technique is also of value in the upgrading of oils that carry large quantities of lipid associates, like neem, karanja, kusum, undi and khakan. In fact this principle is now embodied in the two-solvent continuous miscella refining technique employing alkali, in which the refining factors are only slightly above the theoretical.

Use of furfural: Heating karanja oil with three parts of furfural at 70°C for 30 minutes followed by cooling gave an oil in 79 per cent yield in which the free acidity had been reduced from 5.9 to 2.8 per cent, and the disagreeable odour removed.[247a] Further alkali refining and bleaching, or even bleaching alone, gave an excellent reduction in colour. Neem oil was similarly benefited by three furfural extractions.

Distillation: Commercial vacuum distillation offers a means of upgrading unconventional Indian oils. Three variations are employed.[248]

i) Distillation of the lipid associates along with free fatty acids could leave behind an oil amenable to use. Karanja oil is an example, and from crude neem oil, odorous materials can be removed by distillation, though not bitters. Pisa fat is similarly upgraded.

ii) Sometimes splitting the oil into fatty acids followed by distillation will achieve removal of undesirables. Thus if neem oil is first deodorised by distillation, and then further split and distilled, fatty acids free of bitters and of excellent quality are obtained. Nahor oil, split and distilled, leaves its colour and flavour behind. So does undi oil.

iii) Stripping of khakan oil with steam under high vacuum removes all the odour and most of the colour, and the resulting oil on splitting and distillation yields excellent fatty acids.

B. Upgrading and End-uses of Specific Oils

Subsidiary oils of various categories will now be reviewed. They fall into two broad categories; these cut across the Groups under which these oils have been considered so far, which is based on origin. However the code numbers given to them on that basis will be retained.

The first category consists of those oils which have considerable refining and bleaching problems, and whose edibility even after upgrading is open to question. Table 15 (p. 298) lists these oils, along with their fatty acid composition and unusual constituents.

The third category, listed in Table 19 (p. 305), consists of oils whose composition makes for either industrial or medicinal outlets. These oils may or may not be upgraded before use.

D1. NEEM OIL

Neem oil is obtained by ghani and expeller pressing, or by solvent extraction, either from whole dried fruit, or depulped seed or kernels (which carry about 45 per cent oil). The oil has a dark greenish-brown colour, a repulsive garlic-type odour, and a bitter taste caused by the presence of various compounds which have been described (page 186). The acid value frequently lies between 5 and 25, and both the crude bitters (AV 29) and odorescent compounds (AV 8) present, apart from free fatty acids, contribute to the titrable acidity.[249]

Treatment with concentrated sulphuric acid was used in 1923 to upgrade the oil.[250]

Extraction with alcohol has been described (page 297). Repeated extractions with 95 per cent alcohol remove 13 per cent of bitter material, leaving behind 86.5 per cent with its fatty acid level reduced from 5 in the original oil to 1.9 per cent.[251] Alkali refining with a refining loss of 20 per cent yielded an oil of negligible acidity but only slightly reduced colour, which could be bleached to a very low colour (4 Y, 0.4 R, 0.635-cm cell) and was almost bland, with only a suspicion of a bitter taste. This is the general experience. Even an acid value of 30 was reduced on alcohol extraction to tevels of 1 to 1.5.[244,251a]

Refining with alcoholic alkali, as described earlier, combined the effects of alcohol in removing odorous and bitter material and that of alkali in effecting de-acidification. The resulting oil was amenable to further bleaching.

Furfural segregation, as described earlier (page 302), yielded 60 per cent of a raffinate with AV reduced to 2.4 from the original 6.6, and much reduction in odour and colour.[247a] The treated oil could be easily alkali refined and bleached, and in fact bleaching even without alkali refining led to very acceptable colours.

The solubles from alcohol or furfural beneficiation are of value.[138] The bitter principles, constituting about 2 per cent, are general antiseptics or specific medicines, as discussed elsewhere (page 187). The odorescent, sulphur-bearing compounds, constituting 5 to 6 per cent of the oil, are useful in agriculture as pesticides and repellents. The fatty ballast carries sulphur, and on pyrolysis yields a material which has been named pyronimin, and is an excellent denaturant for alcohol. The upgrading of neem oils with alcohol or furfural could thus yield products of commercial value.

Since the odorescent sulphur compounds present in neem oil are volatile at the distillation temperature of fatty acids, subjecting the oil to physical refining removes them.[248] The bitter compounds, constituting 1 to 2 per cent still remain, but do not detract from use of the oil for soap-making. Splitting the oil and distilling the fatty acids leaves bitters behind and gives a distilled product of excellent quality.

Absorption on silica gel of the associated materials present in neem oil has recently been suggested as a means of upgrading neem oil on a

continuous basis to yield specific byproducts and oil.[252] Chromatography on alumina had been successfully applied for the purpose in 1955 in the laboratory.[253]

Neem oil extracted with hexane following prior alcohol extraction and hence free of bitters, showed good nutritional quality in supporting rat growth,[254b] but long-term toxicological studies which would include organ autopsies have not been done. Through proper technology, an edible outlet could thus arise for what has long been regarded as an obnoxious medicated oil. The composition is of the groundnut oil type.[283h,307]

D2. KARANJA OIL

Expressed karanja or pongam oil is a reddish-brown material with an acrid, nauseating and presistent odour and a bitter taste, and usually of moderate free acid level. The bitter, irritating and toxic flavonoids separate out from the oil even on standing.

Upgrading by alcohol extraction of an oil of free acidity 4 per cent removed 17 per cent of material of high acidity (20 per cent), dark colour and strong odour, leaving 83 per cent of raffinate of low acidity (1.6 per cent) but with a colour deeper than the original.[251] Alkali-refining thereafter, followed by bleaching, or even direct bleaching, did not reduce colour, and in fact even intensified it.[251] Optimal non-glyceride removal requires 3 vols of alcohol and the net loss is 13 per cent.[255]

On the other hand furfural extraction yielded 79 per cent of an oil of reduced acidity (2.8 from 5.9 per cent in the original oil), free of disagreeable odour and amenable to further colour-reduction by alkali-refining and bleaching, or even by bleaching alone.[247a]

Alcoholic alkali yielded far better refining results than did alcohol extraction on a karanja oil of AV 5.2 treated with 0.206 N alkali in 2 vols of 90 per cent alcohol.[219] An alcoholic alkali-refined karanja oil was quickly hydrogenated to an IV of 1-2, in contrast with an aqueous alkali-refined oil (IV 29.2 after five hours) and a raw karanja oil (IV 41.0 after six hours).[256]

Other treatments have been particularly useful in reducing the red colour component of karanja oil. Subjecting the oil to the action of 20 per cent of 0.4 per cent sodium chlorite solution under acid conditions (3 N sulphuric acid) made the oil particularly amenable to subsequent alkali treatment, either aqueous,[257] or better still, alcoholic.[219]

Treatment of karanja oil at 100°C with 1.5 per cent of concentrated phosphoric acid added dropwise with stirring, followed by cooling-settling gave a coagulated lump of material.[220] The resulting decanted oil was slightly higher in AV (by two units), but capable of direct bleaching without alkali refining to a reduced red colour. The derived soaps were light yellow and odour-stable on keeping.[220] Glacial acetic acid treatment also removed a considerable part of the colour.[257]

Even just sulphuric acid (30 to 50 per cent) has a colour upgrading effect.[258] Stirring vigorously with 2 per cent of a 2:1 sulphuric acid: water

Table 19. Oils of industrial utility which may or may not be refined[a]

Oil		IV	NS %	Fatty acids% 16:0	18:0	18:1	18:2	Others	Outlet
G1.	Maroti[275]	100	0.3	2		7		16:1cy 49, 18:1cy 27, 18:2cy 12	Medicine
G2.	Kamala[276,277]	157	1.9	9	1	13	12	18:3 conj 58	Surface coatings
G3.	Pinari[282,321]	74	0.7	18	2	8	5	18:1cy 14, 19:1cy 45	Resins?
G4.	Malkanguni:								
	Fruit coat[288a]	95	6.6	22		22	35	18:3 16; also acetic, benzoic, nicotinic and furoic acids	Medicine
	Kerne[287]	100	3.0	24	6	17	18	18:3 30; also above acids	Medicine
H4.	Somraji[284,322]	55	1.7	5	2	1	12	18:1 ep 78	Plasticisers
H5.	Argemone[285,286]	120	1.5	15		29	55	epoxy 2, hydroxy 1.1, keto 1	Surface coatings
I2.	Simul[287]	96		20		45	12	18:1cy 10, 19:1cy 6	Soap
I3.	Kapok[288]	96	1.5	23	1	30	32	18:1cy 9 19:1cy 3, 18:0cy 1, 19:0cy Trace	Soap
J11.	Kapittha[205]	131	1.0	19	7	27	20	18:3 26	Alkyds
K1	Ambadi[280,242,288g-286,280]								
	a)	69	0.9	35	4	34	15	18:1ep 4.5, 18:1 cy 2.9, 19:1cy 2.3	Soap
	b)	103	1.5	20	2	25	47	18:1ep 3.3. 18:1cy 1.2, 19:1cy 3.4	Soap

[a]References given for individual oils are found in the general reference list to Part C

mixture changed the colour to yellow, and an orange precipitate (3 per cent) appeared on standing.[259] Later work showed that optimally, 2 to 2.5 per cent of concentrated sulphuric acid added all at once at ambient temperature, with stirring for 20 minutes, caused 10.7 per cent of material to separate as a gummy lump without raising the acid value of the oil.[255] While raw karanja oil can be hydrogenated only with difficulty, either the oil subjected to alcohol treatment (3 vols) or to concentrated acid treatment, though not greatly improved in colour, could be hydrogenated with the ease of common refined oils.

The phenolic constituents present in the oil can be distilled away with free fatty acids, usually 2 to 4 per cent.[248] The residual oil does not yield an orange colour on exposure to alkali, and can be used for soap-making (see p. 166/7).

Hydrogenation at high pressure (14 kg/sq cm) alters the phenolic compounds present so that they do not give orange colours on contact with alkali.[248] The resultant oil is adequate for making soap with only slight darkening.

Removal of the testa from karanja seed before extraction of oil with solvent markedly improves the appearance of the oil, and decortication of the leathery adherent skins would thus be advantageous. The oil on standing or chilling becomes solid, the solid phase consisting of karanjin (1.25 per cent), a furanoflavonoid with piscicidal and insecticidal activity (see p. 188/9).

Karanja oil has long been used as an illuminant and in medicine. The recent upgrading methods just described have led to its use in soap-making. Some 500 to 1,500 tonnes annually are produced in the organised solvent-extraction sector.[65] Similar amounts may be included in the oils that are annually generated by the KVIC in the form of seed (21,000 tonnes, equivalent to about 3,000 tonnes of oil), as oil (2,000 tonnes) and as soap (48,000 tonnes, equivalent to about 35,000 tonnes of oil), total 40,000 tonnes.

Removal from karanja oil of the toxic flavonoids by self-precipitation at 0° to 4°C, followed by aqueous caustic refining and activated earth bleaching, yielded an oil which when fed to rats showed growth retardation, high total lipids in serum and liver, and a high liver weight and lipid content.[260] The same workers later showed that sedimentation at 0° to 4°C for three days, decantation, steam distillation, alcohol extraction, de-acidification with aqueous caustic soda, and bleaching with 3.5 per cent of fuller's earth yielded an oil capable of easy hydrogenation.[261] The hydrogenated karanja oil (m.p. 42°C, IV 65, 18:1 53, including *trans* 20, and 18:2 10 per cent) showed no growth retardation, or adverse nutritional or toxic effects.[261]

D3. KUSUM OIL

Kusum oil consists of only 37 per cent of triglycerides. The rest of the oil consists of fatty acids esterified to two dihydroxy nitriles (page 189).

The oil on saponification was long known to yield both ammonia and about 1 per cent of hydrocyanic acid, which limited conventional refining efforts.[152o] Use was confined to hair oil (page 164), and to soap-making by small units because of the hard consistency and lathering ability that it conferred despite the drawbacks noted during saponification. The semi-boiled process was employed, and the lye containing obnoxious constituents was discarded.

A procedure was patented in India[262] for preferentially hydrolysing the nitrile esters by treatment with zinc oxide (1.25 per cent), sodium hydrosulphite (2.5 per cent) and water (80 per cent) at 100° to 150°C for three hours. The upper fatty layer consists of the fatty acids derived from the nitriles along with the true glycerides. Treatment with sulphuric acid hydrolyses the small amount of zinc soap, giving a mix of fatty acids and glycerides useful for soap-making.

D4. NAHOR OIL

Nahor oil has a dark red colour and a characteristic and disagreeable phenolic odour. On standing it deposits stearin, and also resinous materials which are the source of the deep colour (Section 6.3, page 189). When made into soap, the deep yellow colour of the latter is transferred to cotton cloth washed in it.[263] A process was reported to have been developed in the fifties to overcome this,[264] apparently based on alumina column chromatography.[265]

An early process for upgrading the oil consisted of conventional strong alkali refining followed by drastic bleaching with active carbon.[152n] Another consisted in treating nahor oil at 90°C with concentrated hydrochloric acid and potassium chlorate to yield a material which in turn yielded a non-staining soap.[263] Later it was shown that 95 per cent alcohol extracted non-glyceride constituents from the oil, following which alkali refining, bleaching and deodorisation yielded a colourless, odourless and tasteless material. The colour had been dramatically reduced from 28 Y, 5.6 R (Lovibond 1-cm cell) to 0.8 Y, 0.2 R, as had the original specific gravity, refractive index, acid value, saponification value (from 203.2 to 197.7) and iodine value (from 81.1 to 76.6).

While the content of unsaponifiable matter is only 2 per cent, that of non-glyceride associates is as high as 15 per cent. However the fatty acids distilled after splitting are of excellent quality, and are hydrogenated with ease.[248] The edibility of refined nahor oil has not been examined.

D5. UNDI OIL

The oil has been described in some reports as viscous, dark green and of a disagreeable odour. On standing it deposits stearin. Undi oil also carries as much as 10 to 13 per cent of a resinous material; in the past this has been isolated and employed as a varnish, often in admixture with the resin exudate of the dhupa tree.[152a] The oil itself has traditionally been considered inedible and used for illumination, and as a coating on country

boats to prevent fungal infestation. The medicinal uses of undi oil, and the constituents responsible, are considered elsewhere (Section 6.3). Prolonged contact with iron parts or standing in iron containers causes darkening of the oil.

Aqueous alkali refining in two stages using strong caustic soda solution (15 to 20 per cent) in slight excess is effective in refining undi oil, but the red colour component persists.[266] Alcohol extraction led to an excellent reduction in the red colour component (Table 17, p. 301).

Counter-current extraction of dark green undi oil of AV 40.3 with 2 vols of 90 per cent alcohol reduced the AV to 2.0, and greatly improved the colour to 4.1 Y, 0.8 R (1-cm cell).[219] The yield of the oil was almost theoretical.

Splitting the oil followed by distillation yields fatty acids of quite light colour and very faint odour easily hydrogenated to stearic acid.[248]

The edibility or otherwise of refined undi oil has not been explored.

D6. RAYANA OIL

The viscous but clear reddish-brown oil of disagreeable odour and bitter taste expressed from the seeds or kernels of *Amoora rohituka*[152p] has a long history of medicinal use. These characteristics have been reported to be due to phenolic or resinous components of unknown nature.[152p] The oil was easily refined and bleached to a clear, brownish-yellow oil, which in turn could be hydrogenated without difficulty.[267]

The soap is said to be yellow, and to lack body, but to be highly resistant to rancidity,[268] which may suggest that the antioxidants are phenolic resins.[174]

The composition of the oil (IV 134, linoleic 57, linolenic 8) suggests an outlet in surface coating formulations. Assuming that the oil can be upgraded to edibility, the small proportion of linolenic acid would call for partial hydrogenation to achieve stability, as with soybean oil.

F1. KHAKAN-PILU OIL

The kernels of the 'sweet' variety of pilu, also called khakan (page 102) yield 35 to 44 per cent of an oil with a strong odour and a greenish colour, easily bleached by exposure to sunlight in thin layers in metallic trays.[173] However, such sunlight bleaching promotes rancidity. Bleaching is also effected by treatment with sodium dichromate and dilute sulphuric acid.[246] Bleaching with 0.2 per cent sodium chlorite is almost total, and also leads to partial deodorisation.[246]

The unpleasant odour is attributed to benzyl isothiocyanate, derived from a glucosinolate precursor, and to the presence in the unsaponifiables of symmetrical benzyl urea and benzyl thiourea.

Extraction of the macerated seed with alcohol, followed by hexane extraction, yields an oil that is amenable to normal aqueous alkali refining and earth-carbon bleaching.[239] On this showing, it is probable that refining

with alcoholic alkali will also yield khakan oil of good quality for use in soap-making.

Steam stripping at 270°C under high vacuum removes the unsaponifiable matter with its attendant problems of colour and odour.[248] The oil after stripping may well respond to alkali refining. It can also be split and fractionally distilled to yield lauric (21 per cent) and myristic (53 per cent) acids of excellent quality.[248] The edibilily of suitably-beneficiated khakan oil remains to be studied.

F2. PISA FATS

The kernel fat, with 88 per cent lauric acid, is obviously a material with remarkable potential. If of low acidity, conventional aqueous refining is adequate, though the aromatic odour tends to persist. Simple crystallisation from alcohol several times yields almost pure trilaurin with AV 0.1, IV 0.5, SV 263.2, no unsaponifiables, and m.p. 44.4°C.[246] Pisa fats of high acidity are upgraded only poorly through the use of alcohol, even the free acidity being only slightly reduced.[246] In fact even extracting the hexane miscella of pisa fat with methanol dose not reduce free acidity, but beneficiates the oil by reducing both its colour and odour, while still giving a good fat yield.[212] This procedure should meet the need for use of pisa fat for soap-making.

Pisa seed is stated to contain a volatile lauryl ester which is believed to have potential as a flavouring agent.[269,270] Its removal during oil extraction is apparently considered desirable.

The lipid associates of pisa fat, which includes the ester, constitute 4 to 5 per cent. These volatilise at about the same boiling point as lauric acid. Vacuum distillation of the whole fat removes these entities, after which the residual oil can be split and fractionally distilled to yield very pure lauric acid.[248]. The preferred use of pisa kernel fat or fatty acids would be in the soap kettle as a lather component, or as a source of chemicals.

The hulls and fruit, constituting 47 per cent of the pisa seed, also carry about 21 per cent of fat with a range of fatty acids (lauric 13, palmitic 26, oleic 54 and linoleic 6 per cent), which are again of soap-making value.[271] When pisa seed is crushed as a whole, this oil would obviously influence the composition of the total composite fat from shell and kernel.

F3. CHIRANDI OILS

Like pisa seed, the seeds of *Litsea glutinosa* also carry fat both in the pulp and shell taken together, and in the kernels. The oils recovered from whole seed and kernels (forming 61 per cent, and containing 54 per cent oil) in one study showed rather conflicting characteristics.[239] The whole fruit oil (yield 4.9 per cent) had IV 45.6, SV 256.8, and the kernel oil (yield 60 per cent) had IV 41.0, SV 248.7. Another report shows an IV of only 6 for the kernel oil, and a 96 per cent content of lauric acid.[283l] The oil from whole seed was black in colour, with a strong aromatic odour and disagreeable taste.[152q] Even for use in soap manufacture, which seems

indicated by its composition, the oil would have to be refined. No work to this effect has been reported.

I5. PALAS OIL

The large kernels of *Butea monosperma* contain about 20 per cent of a yellow tasteless oil, even though the cake left behind has a repulsive smell and carries flavonoid glycosides (Section 6.3, p. 194). The oil has IV 85, and is of the equal SOL type.[272] Little other information is available.

J7. PAPAYA SEED OIL

The numerous black seeds of the papaya (which strongly resemble pepper corns) have a cress-like odour.[152r] The seeds yield a sulphur-containing basic substance termed carpasemine, which has been identified as a benzyl thiourea. Since this is known, as in khakan fat, to enter the unsaponifiable constituents of the oil, special refining procedures such as the use of alcoholic alkali, steam stripping or use of sodium chlorite may be necessary to upgrade papaya seed oil.

The oil has IV 68, and 77 per cent of oleic acid accompanied by less than 1 per cent of linoleic acid, thus resembling olive oil.[199] The edibility has not been rigorously ascertained.

J8. SITAPHAL SEED OIL

Annona squamosa seeds are used to stupefy fish, and the hexane-extracted oil carries about 6 per cent of a toxic principle which separates out on chilling the miscella (see page 196). This material is sensitive to alkali and is stated to be destroyed on refining the oil with a 50 per cent excess of aqueous caustic soda.[200] Sitaphal seed oil of free acidity 3.7 per cent was neutralised with a 60 per cent excess of 16° Bé lye and then decolourised with 2.2 per cent bleaching earth-carbon (10:1) to give a very light oil (0.4 Y, Nil R, 0.635-cm cell).[202] Actual edibility has not been established. The oil resembles groundnut and should be excellent for soap-making. Recently 9.8 per cent of isoricinoleic acid (9-hydroxy-*cis*-12-octadecenoic acid) has been isolated from sitaphal seed oil.[273]

Sitaphal seed oil has insecticidal properties (see page 323, under D1. NEEM).

J9. SAPOTA SEED OIL

The seed oil of *Manlkara sapota* has an IV of 60, and an oleic acid content of 65 per cent, accompanied by just 1.5 per cent of linoleic acid in one analysis,[320] and 5 per cent in another.[316A] The seeds carry 1 per cent of a saponin which is not likely to enter the oil, but also 0.08 per cent of a bitter compound, sapotinin.[152k]

J10. GRAPESEED OIL

The cold-expressed oil can be obtained only in very low yield since the oil content of the seed is only 6 to 20 per cent.[152t] This oil is stated to be

sweet, while the hot-expelled oil is described as brown in colour and 'very bitter'.[152f] The oil from whole ground seeds or kernels, whether extracted by expelling or by solvent, is said to be used as such for soaps, or as an edible oil after refining and bleaching.[274] The very high linoleic acid content (66 per cent) would make this a welcome edible oil.[283j,321]

10.3 Oils of Industrial Utility which may or may not be Refined

These oils vary in nature, but are all inedible from a variety of causes, such as the presence of cyclopropene, cyclopentene, epoxy, keto or conjugated fatty acids, or of excessive linolenic acid. Table 19 (p. 305) lists these oils along with their characteristics, fatty acid components and the outlets that appear most appropriate.

G1. MAROTI SEED OIL

The oils of *Hydnocarpus wightiana* (maroti) which flourishes in south India, and that of *H. kurzii* (chaulmoogra), which grows in Bengal and Assam, have long been specific for the treatment of leprosy In India (page 191).

The oils contain three cyclopentene fatty acids; to the 5-membered ring carrying a double bond is attached either a 10-carbon saturated, or a 12-carbon saturated or a 12-carbon monoene aliphatic chain to yield hydnocarpic, chaulmoogric and gorlic acids. The composition of the two oils is as follows:[275]

	Maroti	Chaulmoogra
Hydnocarpic ...	48.7	34.9
Chaulmoogric ...	27.0	22.5
Gorlic ...	12.2	22.6
Normal fatty acids ...	12.1	20.0

Even crude expressed maroti oil is of a pale greenish-brown tinge, and is easily refined and bleached to a water-while colour.[246] There would seem to be little necessity for this.

G2. KAMALA SEED OIL

As described earlier (page 272/3), the oil within the kamala seed polymerises so easily and spontaneously that the problem is to restrain this by extracting seeds that are absolutely fresh with solvents like benzene. Antioxidants like hydroquinone and α-naphthylamine (0.5 to 1.0 per cent) also stabilise the oil, and are stated to be without effect on its drying properties.[152d]

The oil has an unusual character. About 72 per cent of the fatty acids consist of a distinctive member, termed kamlolenic acid, with triene conjugation and a hydroxyl group at the terminal carbon atom;[276,277]

$$HO.H_2C(CH_2)_3CH{=}CH{-}CH{=}CH{-}CH{=}CH(CH_2)_7\ COOH$$

If kamlolenic acid is represented by K and other normal fatty acids by N, the oil has been deduced on the basis of solvent crystallisation data, mean molecular weights, hydroxyl values, fatty acid analysis, and glycerol content to consist of four glyceride types represented as follows;[278,279]

$$\text{KK—}\left[\begin{matrix}\text{KKK}\\ \\ \text{KKK}\end{matrix}\right. \qquad \text{K—}\left[\begin{matrix}\text{KKN}\\ \\ \text{KKN}\end{matrix}\right. \qquad \text{KK—}\left[\begin{matrix}\text{N}\\ \\ \text{N}\end{matrix}\right. \qquad \text{K—}\left[\begin{matrix}\text{N}\\ \\ \text{N}\end{matrix}\right.$$

No crystallised fraction was found to be free of bound glycerol, which does not support an alternative hypothesis that all the kamlolenic acid is present as lactones, and that the normal fatty acids are esterified not with glycerol but with a diol.[280] Modern methodology should help to settle the very unusual assembly of fatty acids in kamala seed oil.

Kamala seed oil dries with great rapidity to yield attractive glossy wrinkle finishes. Kamala seed oil extracted with linseed or sesame oils to yield a 1:4 mixture called Friol is another form in which the oil can be used in quick-drying surface countings (Section 9.5, p. 273). The oil has also been modified with pine resin to yield a water-thinnable coating.[281]

G3. PINARI SEED OIL

Though the fats in the seed coat and kernel of *Sterculia foetida* are of a different nature, difficulties of separation result in the two being extracted together.[174] The kernel fat carries a very high proportion, 59 per cent, of cyclopropene fatty acids, 14 per cent being malvalic and 45 per cent sterculic.[282] On heating to above 200°, it polymerises in a strongly exothermic way into a jelly-like mass.[152e] This would suggest its use in surface coatings or resins of some type.

The oil is definitely inedible. Even at a 5 per cent level it causes death in experimental animals.[152e] Information on upgrading the oil is lacking.

G4. MALKANGUNI SEED OIL

Both the fruit coat and the kernel of *Celastrus paniculatus* carry fat, but these fats are not dissimilar in nature (Table 19, p. 301). They are also unusual in many ways. In addition to common fatty acids, these fats contain acetic, benzoic, nicotinic and furoic acids esterified with two sesquiterpene alcohols (see Section 6.3, p. 192/3).

The fruit coat (aril) has 30 per cent fat which carries 6.5 per cent of unsaponifiable matter.[283a] This includes the unusual esters of sesquiterpene alcohols. The kernel fat is a deep brownish or reddish-yellow material with an unpleasant taste. It thickens on keeping to a honey-like consistency.[152h]

Oleum nigrum is a black liquid traditionally obtained by destructive distillation of whole malkanguni seeds, and specifically used for the treatment of beriberi (see Section 6.3, p. 192/3).

H4. SOMRAJI OIL

The oil from the achenes of *Vernonia anthelmintica* achieved contemporary fame as the first oil in which a natural epoxy acid, named vernolic acid, was discovered in 1952, the quantity (78 per cent) also being high.[284] The achenes themselves contain a bitter resin acid. The oil, though not bitter, carries 2 per cent of a resin, and the unsaponifiables have brassicasterol, stigmasterol and another low-melting sterol.[152f] The oil has long been used in Indian medicine (Section 6.1, Table 5), while modern outlets as plasticisers have followed the discovery of the high content of natural epoxy acid.

H5. ARGEMONE SEED OIL

The obnoxious oil of *Argemone mexicana* is one that India could well do without because of its role in the incidence of glaucoma and possibly epidemic dropsy in those who consume it inadvertently even in small amounts (Section 6.3, p. 193/4).

Apart from palmitic 15, oleic 29 and linoleic 55 per cent, argemone oil contains several unusual constituents. About 2 per cent of an epoxy and 1.1 per cent of a hydroxy fatty acid have been isolated.[285] Three 18-carbon fatty acids, with a keto group in the 9, 11 and 13 positions, are present in about equal amounts, though together making up just 1 per cent.[286] Also present is an alkaloid termed sanguinarine, and the objectionable physiological effects have been traced to the effect of sanguinarine potentiated by the keto acid group (Section 6.3, page 193/4). Potential use of argemone oil would lie in surface coatings.

I2. SIMUL SEED OIL

The presence in the oil of *Bombax ceiba* of 10 per cent of malvalic and 6 per cent of sterculic acids[287] condemns it to soap use, the other fatty acids being palmitic 20, oleic 45 and linoleic 12 per cent. This is because cyclopropenoid fatty acids have profound biological effects and are also suspected cocarcinogens (Section 6.3, p. 192). The quantity present here is rather too large to be rendered inactive by acid deodorisation (as for cottonseed oil) or by slight hydrogenation.

I3. KAPOK SEED OIL

The same difficulty attends the seed oil of *Ceiba pentandra*, which carries nearly 13 per cent of total cyclopropene and 0.7 per cent of cyclopropane fatty acids, besides about 30 per cent each of saturated, oleic and linoleic acids.[282] Feeding trials showed good rat growth, but abnormality in reproductive performance, with low conception, low weanling weight of pups, and high pre-weanling mortality.[287A] Soap-making would be the appropriate outlet.

J11. KAPITTHA SEED OIL

The tiny seeds of *Limonia acidissima*, the wood apple, yield a yellow oil

with an orange tinge which carries no unusual fatty acids.[265] The acid value was low (0.8 per cent), but the presence of 26 per cent of linolenic and 20 per cent of linoleic acids suggests only surface-coating use. Upgrading of the oil was not attempted.

K1. AMBADI SEED OIL

The brown oil of *Hibiscus sabdariffa*, of FFA 2-3 per cent, showed a high refining factor of 5 but was easily refined and bleached to a very light colour (9 Y, 0.8 R, 2.54-cm cell).[206] The oil carries 3 to 4.5 per cent of epoxy acids and 5 per cent of cyclopropene fatty acids, which rule out edible use (pages 192/3). The Halphen response caused by the latter was eliminated by heating the oil with 1 per cent phosphoric acid at 90°C for one hour. Storage stability of the refined and bleached oil was poor, a high peroxide value of 350 developing in just 120 days.[206]

The IV in two studies of Indian ambadi seed oils (Table 19) showed a rather large variation, being 69 and 103.[288,289] Ambadi seed oil is now being produced in commercial quantities by solvent extraction in India,[65] though its outlets are not known.

CHAPTER 11

Oilcakes Derived from Indian Oil-bearing Materials

11.1 Classification of Oilcakes

The oilcakes that result from the extraction of oil from Indian oil-bearing materials will be considered in three groups.

First come all the oilcakes that are derived from the nine materials that constitute Group C, namely oil-bearing materials which are themselves the byproducts of cultivated crops. Some of these oilcakes are edible, like those from ricebran, maize and tobaccoseed, and are used as direct or compound animal feeds. Certain others are not edible, like the oilcake from rubberseed, spent coffee grounds and tea seed. Yet other oilcakes in this group must be considered of doubtful edibility until demonstrated to be so.

The second lot of oilcakes are definitely inedible. Some have striking properties as fertilisers or insecticides, which will be considered here. The actual constituents revealed in recent research, and any medical investigations, have been reviewed earlier in Section 6.3.

The third group of oilcakes are those whose status in terms of edibility is not known. *Prima facie* some are likely to be edible, and others not.

Table 20 shows specifications from typical Indian non-transferable specific delivery contracts for trading purposes in edible oilcakes, both expeller and solvent meal, termed extractions.[65] These represent the fair average quality of commercial Indian oilcakes.

The essential amino-acids in unusual Indian oilcakes are shown in Table 21.

11.2 Oilcakes Derived from Processing the Byproducts of Cultivated Crops

The oilcakes derived from the nine oil-bearing materials in this category, termed Group C in this volume, are shown in Table 22, which indicates gross cake composition, unusual constituents in the oil that was removed and in the cake itself, and cake edibility or otherwise.

Table 20. Contract specifications for edible Indian oilcakes within the country[a,b]

Oilseed	Type of cake	Oil and albuminoids % min	Fat % min	Fibre % max	Sand and silica % max
Sesame	Extractions	a) 45	1.5	8	2.5
		b) 40	1.5	10	2.5
Cottonseed	Decorticated expeller	47	7.5	13	2.5
	Extractions	a) 48	1.5	5.5	2.5
		b) 44	1.5	11	2.5
Rapeseed	Expeller	40	7.5	12	2.5
	Extractions	35	1.5	12	2.5
Coconut	Extractions	21.5	1.5	15	2.0
Nigerseed	Extractions	31	1.0	13	1.5
Safflower	Decorticated extractions	35.5	1.5	24	1.5
	Undecorticated extractions	21.5	1 5	35	2.0
Groundnut	Expeller	54	7	13	2.5
	Extractions	a) 50	1.5	13	2.5
		b) 45	1.5	13	2.5
Soybean	Extractions	a) 49	0.5	3.3	2.5
		b) 44	0.5	7	2.5
Sunflower	Expeller	38	12	—	2.5
	Extractions	32	—	22	2.5
Ricebran	Extractions	a) 16	1.0	10	5
		b) 14	1.0	10	8
Sal seed	Extractions	10	2	3	1

[a]As laid down by various trade bodies

[b]Other provisions as follows:

i) Moisture max. variously specified, but above values are on moisture-free basis

ii) All specifications include freedom from castor seed, cake and husk

iii) Extracted fat from expeller cakes must have below 5 per cent FFA

iv) Graded discounts are applied when above provisions are not met, with rejection options as well

v) Specific provisions are made for specific uses, for example, gossypol levels in cottonseed expeller and extractions, allyl isothiocyanate in rapeseed extractions, or urease activity in soybean extractions

C1. RICEBRAN

Ricebran itself has been since antiquity a well-established animal feedstuff in India, and the solvent-extracted meal finds similar use. In 1983, some 900,000 tonnes of deoiled ricebran were thus utilised in India, and a further 295,000 tonnes exported for the purpose.

Because of variations in bran quality, the meal is tailored to two export specifications (Table 20). The higher grade, termed 16 : 5 : 9 in the trade, has a minimum of 16 per cent protein and 5 per cent sand and silica, but the latter is negotiable up to a 9 per cent level with discounts. The other, of inferior quality, is similarly termed 14:8:10. Both grades carry maxima of 10 per cent crude fibre, and 1 per cent residual fat content.[65]

Though the protein content of ricebran meal is low, this protein is of exceptional amino-acid quality (Table 21). The levels as g protein/16 g nitrogen are as follows,[65] with the values for soybean protein shown in parentheses for comparison: lysine 5.75 (6.32), methionine 3.75 (1.34), cystine 1.25 (1.78), threonine 3.70 (3.94), tryptophan 3.45 (1.38), leucine 6.75 (7.71), isoleucine 4.95 (5.38), phenylalanine 4.50 (4.94), tyrosine 5.80 (3.18) and valine 6.05 (5.25). Upgrading the protein level through sieving or air-classification would furnish a top-quality feedstuff (p. 255).

Ricebran stabilised using hydrochloric acid (p. 247) was an excellent feedstuff for layers and broilers.[127A]

C2. TAPIOCA SEED

With a protein level (calculated from kernel values) approaching 50 per cent, and low crude fibre levels of 3.5 per cent, tapioca seed cake could have value as a feedstuff.[128] Its edibility has yet to be tested in India, and the presence of cyanogenic materials in the tubers would suggest caution.

C3. MAIZE GERM

Corn meal with 30 per cent protein is of course a well-known animal feedstuff. It is used in India in commercial livestock feeds, though the 10 per cent crude fibre level is high.[152u]

C4. TOBACCO SEED

Nicotine is stated to be absent from the seed,[152v] and even ground whole tobacco seeds have in the past been given to cattle. The protein content is 27 per cent, and tobacco seed meal has found acceptance in the USSR as a cattlefeed.[129] Tests in India show that it can be fed without detriment to buffaloes as the entire ration, and to milch cows at 25 per cent of the concentrate ration.[323a] The ash content is high, not from acid-insolubles but from P_2O_5 (1.85), CaO (0.65) and K_2O (1.13 per cent). Judging by rather old values (Table 21), the amino-acid balance is poor, several (lysine, methionine, cystine and tryptophan) indeed being almost marginal. The cake is valued for fertiliser application.

Table 21. Essential amino-acids in the proteins of some Indian oil-bearing materials[a]

	Lys	Val	Met	Cys	Thr	Try	Phe	Leu	Isl	Tyr
C1. Rice bran	5.75	6.05	3.75	1.25	3.70	3.45	4.50	6.75	4.95	5.80
C4. Tobacco seed[158c]	1.6	6.7	2.2	1.1	4.2	1.5	5.7	10.5	5.3	4.1
D1. Neem[247,248]	3.3	3.6	1.1	0.3	3.2	1.2	3.8	6.5	2.6	2.1
	3.8	5.7	1.0	3.6	5.3	1.8	3.5	8.5		4.4
D2. Karanja[249]	6.21	4.21	3.00	Nil	3.14	2.04	2.00	8.12	2.24	4.36
D3. Kusum[248]	4.2	6.5		2.9	7.3	?	3.8	10.4		5.6
D6. Rayana[250]	2.8	5.8		1.9	5.6	?	6.0	10.6		Nil
E1. Mahua[251]	4.5	4.9	0.8	3.2	3.0	?	4.5	6.5	2.2	1.5
E2. Sal[160f]	5.7	5.9	1.7	2.2	7.8	?	3.4	12.0		4.3
Sal[231i]	4.7	6.5	1.3	1.2	3.6	?	5.0	8.7	3.7	?
E4. Kokum[248]	3.4	5.0	4.4	2.2	5.5	?	4.7	8.1		3.3
E6. Phulwara[160e]	4.03	4.30	1.03	2.76	4.03	?	3.77	9.16	7.00	9.16
Phulwara[250]	4.3	6.0		2.6	6.2	?	6.2	11.3		4.6
Phulwara[252]	5.1	5.9	1.6	0.4	3.7	1.0	6.5	3.0	7.5	3.9
F1. Khakan[231f]	5.5	5.8		2.4	6.0	?	?	14.5		3.8
F2. Pisa[249]	2.5	6.9		3.8	5.3	?	6.1	8.1		6.8
G1. Maroti[248]	6.0	6.5		2.5	5.7	?	5.4	7.6		Nil
I3. Kapok[250]	4.0	4.5		2.7	6.6	?	4.7	7.1		3.3

I6. Teak[340A]	3.64	6.18	Nil	?	2.91	Nil	4.00	8.00	4.93	0.73
I7. Tamarind[358]	4.8									
J1. Mango kernel[348]	6.8	6.8		1.9	7.2	?	3.9	7.1		Nil
J3. Water melon[354]	2.9	4.6	2.4	1.0	3.9	1.8	5.0	6.6	3.5	2.6
J4. Musk melon[335A]	3.38	3.51	0.47	1.65	3.19	1.40	4.64	6.37	0.33	0.95
J9. Sapota[340]	5.6	6.5		3.1	7.0	?	4.2	9.2		3.8
K2. Okra[343]	8.7	4.9	2.1	—	3.8	2.0	4.7	7.9	4.1	3.2
K3. Tomato[334a,335b]	5.2	3.1	1.0	—	4.1	0.8	3.6	6.2	3.3	3.7

*References given for individual proteins are found in the general reference list to Part C

Table 22. Oilcakes derived from processing the byproducts of cultivated crops: Group C[a]

Oilcake derived from	From whole seed W, or kernel K, by expelling E or solvent extraction S	Protein %	Crude fibre %	Total ash %	Unusual constituents[e] In oil		In oilcake	
C1. Ricebran[65,382]	Bran/S	14	6	4[c]	None	E	High crude fibre, high sand and silica	E
C2. Tapioca seed[128]	W/E[b]	50	6.5	3.5	None	E	Possible cyanogenic glucosides	N
C3. Maize germ[152u]	Germ/S	18	10	3	None	E	None	E
C4. Tobacco seed[129,152c']	W/S	30	17	10	None	E[d]	None	E
C5. Rubber seed[152w,239,324a]	K/S	25	5	9	None	Perhaps E	Cyanogenic glucosides, oil polymers	N
C6. Tung seed[152d']	K/E	20	—	—	18:3conj. acid	N	Oil polymers, spontaneous combustion	N
C7. Jute seed[128]	W/S	22	19	7	None	E	High crude fibre	E?
C8. Spent coffee[137,366b]	Grounds/S	16	22	3.7	Unsap.13%	E?	High crude fibre	N
C9. Tea seed[138]	K/E	8	30	2.5	Unsap.3.7%	E	Saponins c.10%	N

[a]References given for individual oilcakes are found in the general reference list to Part C
[b]Calculated from kernel values
[c]Acid-insol. ash per cent
[d]Not legally permitted for edible use in India
[e]E Edible, N Non-edible

C5. RUBBER SEED

The meal has a protein content of 32 per cent, and bullocks fed on it maintained positive nitrogen balance and showed no ill-effects. It could also be used as a 10 per cent replacement for coconut cake in feeding pigs without any effect on rate of growth, feed efficiency or carcass characteristics.[323a] However, at a 30 per cent level in weanling rats, a black foetid diarrhoea occurred, and was attributed to necrotic enteritis. There are two nutritional hazards: the tendency of the oil to polymerise in the seed even on short storage (this could be even faster in expeller cake),[132] and the presence of the cyanogenic glycoside linamarin (Section 6.3, page 186), though in lesser amounts (70 to 220 ppm) than in linseed cake.[152w,324a]

C6. TUNG SEED

The oil present even in the seed itself is liable to easy polymerisation because of the presence of 65 per cent of α-elaeostearic acid. White kernels turn brown, and after 160 days, only 12.4 per cent of oil could be expelled against 16 to 17 per cent during the first 100 days of storage.[134] Even tung cake cannot be stored for more than a month without the oil content being appreciably reduced. The cake is liable to spontaneous combustion, especially if derived from processing kernels that are not fresh. A toxalbumin was earlier reported to be present.[152y] Further work has identified a heat-labile protein, possibly a protamine, and a heat-stable material which consists of the diesters of a polyol with an unsaturated keto acid, an unsaturated keto alcohol and a polyhydroxy acid.[324A] Fertiliser use, or as a filler in moulded boards, is indicated.

C7. JUTE SEED

While the protein content of the solvent-extracted whole seed meal is 22, the ash content 7 per cent, and the acid-insoluble ash content 0.2 per cent, the crude fibre level of 19 per cent for the wholeseed meal is rather high for unrestricted edible use.[136] Nor has the edibility of the cake been demonstrated, while the bitter taste of the expelled oil also suggests the need for caution in cake use.

C8. SPENT COFFEE GROUNDS

The residue from the solvent extraction of spent coffee has 16 per cent protein and only 3.7 per cent ash, but the crude fibre level (22 per cent) in one study was high,[137] and moderate in another[355b]. The oil itself has an exceptionally high content of unsaponifiables (13 per cent).[137] Roasted coffee beans carry caffeine and tannins besides, and the cake is of a deep brown colour. Rats on a diet of coffee seeds ate very little and died in a week, and those on coffee grounds in two weeks,[355b] ruling out use of coffee grounds meal as animal feed. The product is already in use as a fertiliser in India.

C9. TEA SEED

Tea seed kernels have a very high content of tannins (8 per cent), hence the level in the solvent meal (after the 25 per cent of oil present has been removed) would be well over 10 per cent. Saponins are also present at 10 per cent level, the protein level is low (8 per cent) and that of crude fibre high (30 per cent).[138,292c] All point only to fertiliser use.

11.3 Oilcakes that are Inedible: First Group

Table 23 lists details of the inedible oilcakes derived from various oilseeds of Groups D, E and F.

D1. NEEM

Neem fruit pulp suspension (1 kg macerated in a muslin bag in 1000 litres of water) sprayed on horticultural produce (1 ha) served in practice to deflect an actual locust invasion, the effect lasting two to three weeks.[325] Silaged neem pulp and pulp water were of marked benefit in a crop of sorghum.[326]

Neem cake has both fertiliser and insecticidal value, and apparently some feed value as well. Many herbs and aromatic plants, and citrus fruits, record higher yields with neem cake, which is also protective against white ants.[326] Nitrification in the soil is inhibited when neem cake is employed; after nine weeks the figure is just 43 per cent, which is about half the usual value.[247b] Among six meliacins present in the cake, a new compound, epinimbin, was found to be the key compound inhibiting soil nitrification, and its performance matched that of a commercial nitrification retarder, nitrapyrin.[326A] It was also antimicrobial in soil. In flooded rice, biological nitrogen-fixation by blue-green algae increased when soils were treated with neem cake.[322a] In blends of 20 to 25 per cent neem cake with urea, a saving of 25 to 50 per cent is effected in urea usage, with increases in yield of 23 per cent (42 trials) in rice and 16 per cent in sugar cane.[328a] Rice yields were elevated both in the wet and dry seasons.[327b] In India, a neem cake-urea blend with 37 per cent N_2, is a commercial product,[327c] and in the USA, Margosin-O of Vikwood Ltd. has received clearance from the Environmental Protection Agency for use with non-food plants.[328b]

In cattlefeed, 3 per cent neem cake, mixed with molasses and thoroughly dried, acts as an excellent vermicide.[326] The bitters of neem cake have no effect on rumen microbial synthesis, and were not toxic even when administered interperitoneally to animals.[329] However, the cake is not acceptable to animals in high concentration, debittered cake having greater acceptability.[330] Neem cake has supported growth of cattle at a 10 per cent level in the concentrate,[324c] and of sheep at 25 per cent level.[331] Chicks show poor growth and evidence of hepatotoxicity,[332] and for both poultry and growing calves, some treatment such as alkali washing of neem cake is necessary.[324c,324d] However, some factor affecting haematopoiesis is present,[324e] and the poor amino-acid balance of neem-seed proteins

(Table 21) makes for poor growth in young animals in any case.[330] The fruit pulp cake supported growth of growing sheep at a 25 to 50 per cent level, and even 75 per cent could be used in the maintenance rations of adult animals.[324f]

Neem kernel cake that had been freed of bitter and odorous compounds by successive exhaustive extraction with alcohol and hexane supported the growth of rats.[347] The net protein utilisation was comparble to that of groundnut cake and the calcium and phosphorus contents were higher. Since methionine and cystine were the the first limiting amino-acids, use of supplementary casein had a markedly beneficial effect.

The insecticidal effectiveness of neem cake, and of neem products generally, is wide-ranging and striking. Many plant parasitic nematodes are killed, and larval hatch is inhibited, by neem oil, neem cake and water-soluble extracts.[327d] Root-knot of okra, tomato and aubergine (brinjal) caused by nematodes is controlled.[327e] Water-extracts of neem leaves destroyed two other root-knot nematodes.[327f] Neem cake diluted with sand is used in India against tobacco plant nematodes and against white ants. As an insecticide, neem seed or kernel suspensions have been rated as being as effective as Malathion against foliage-feeding insects.[333a] Water-extracts of the ground seeds controlled many fruit-flies.[327g] Neem oil emulsions (0.3 per cent) warded off many rice pests,[333b,333c] and retarded the growth and development of all hopper species.[327h] Against the cotton leafworm however, the oil was inactive but the seed extract effective.[327i] A 4:1 mix of neem oil and sitaphal seed oil (itself an insecticide, page 310) in 5 to 20 per cent concentration was superior to all other treatments tried for reducing survival of the rice green leaf hopper, which also transmits a viral disease.[327j] Sunlight degrades effectiveness of neem oil sprays, but in one study it was still effective after six days' exposure.[327k]

Dressing foodgrains with 1 to 2 per cent of neem oil is sufficient toward off many storage pests,[325] including the confused flour beetle.[327l] Sorghum in clay pots could be protected for five months with either neem oil, neem kernel or neem leaf powder.[327l] Neem leaves are very widely used in India for rice storage, and the leaf aqueous extract as a general-purpose household disinfectant.[334]

As modes of extraction of the active insecticidal principles, water, methanol and tertiary methyl buty ether have generally been favoured, and an azeotrope of the three solvents was highly rated.[327m] Against the carmine spider mite, the water extract of the kernels was far less active than the pentane extract.[327n] The presence of sesame oil enhanced the effectiveness of the methyl butyl ketone extract of neem kernels.[327o] Piperonyl butoxide increased five-fold the effectiveness of various neem seed extracts.[327p]

Few insects are unaffected by neem constituents,[333a] which exhibit antifeedant, insecticidal and oviposition-deterrent activity. The antifeedant activity has been linked to the compound azadarachtin, which shows the effect at a concentration as low as 0.04 ppm.[333a] Azadarachtin and related compounds are also held responsible for the insect growth-regulating activity

Table 23. Oilcakes derived from processing oilseeds of Groups D, E and F: all oilcakes inedible[a,b]

Oilcake derived from seed of	From whole seed W, or kernel K, by expelling E or solvent extraction S	Protein %	Crude fibre %	Ash			Unusual constituents in oil and cake
				Total %	Ca %	P %	
1	2	3	4	5	6	7	8
D1. Neem							
a) [323a,323b]	a) W/S	21	28	9.5	0.44	0.68	Oil: 2% bitter constituents, 6% odorescent sulphur compounds
b) [254a,323c,324b]	b) K/S	43	14	7.0	1.00	1.90	Meal: All the above, high crude fibre, high ash, 1.5% tannins
c) [323d,324f]	c) Fruit pulp/s	2	31	13.1	1.27	0.26	Fruit: Many of the above
D2. Karanja[152x,324i,325]	K/S	34	6	3.5[ci]	0.6	0.6	Oil: Furanoflavones like karanjin, pongamol, etc. Cake: Above, also 13.5% mucilage
D3. Kusum[149,152o,324c]	K/S	22	10	5.3[cii]	2.1	1.1	Oil: True glycerides only one-third, rest hydroxynitrile esters Cake: Nil
D4. Nahor[152n,263]	K/S	32	—	—	—	—	Oil: Resinoids, three phenolic coumarins Cake: Nil
D5. Undi[152a]	K/S	29	6.2	5.0	1.5	2.0	Oil: 10-30% of four 4-phenylcoumarins Cake: Nil
D6. Rayana[267,268]	No details available regarding composition						Oil: High %age of bitter resins Cake: No details

E1. Mahua[152,168e,247b]	K/S	16	8	6.3[c iii]	0.15	0.37	Oil: None Meal: 6-8% toxic saponins, 1.2% tannins, enzymes Seed coat: 20% dehydroquercetin and quercetin
F1. Khakan Pilu[152i,231m]	W/E	27	---	17.0	—	1.7	Solvent oil: Dibenzyl urea, dibenzyl thiourea and a thioketone Expelled oil: Above; also benzyl isothiocyanate Meal: Glucotrapaeolin, quercetin and rutin
F3. Chirandi[239]	W/E	24	—	—	—	—	Oil: Strongly aromatic odour, disagreeable taste, deep black colour Cake: No details

[a]References given for individual oilcakes are found in the general reference list to Part C
[b]See Chapter 10 for details of oils
[c]Acid-insoluble ash %: (*i*) 0.8; (*ii*) 3.1; (*iii*) 1.4 respectively

at each larval stage. They are believed to act by two mechanisms: by stimulating specific detector receptor neurones, and by instituting the firing of neurones which signal the presence of phagostimulants.[327q] Through disturbance of the endocrinal system and hence of hormonal pathways, reproduction of various insects is severely affected at each stage.[327r] The attempt in India is to produce what have been termed 'Neem-rich' products enriched to particular principles, whether antifeedant, aphicidal or oviposition-deterrent.[327s]

D2. KARANJA

When used as a fertiliser, karanja cake retards soil nitrification, and also the decomposition of soil organic matter.[335] Adding an extractive of karanja cake to ammonium sulphate caused ammonia to accumulate in the soil, while the extraction also stabilised soil structure.[231l] In fact both in laboratory experiments and with greenhouse rice crops, the alcoholic extract of the cake was found as effective as a well-established commercial synthetic nitrification inhibitor, called N-serve.[231l] Karanja cake is widely used as a paddy manure.[324g] For sugar cane, a combination with 15 per-cent urea results in a 25 to 50 per cent saving in nitrogen use, and is rated superior to a similar neem cake combination.[327c]

In practice, fertiliser application mingles with other insecticidal effects. Karanja cake controls beetles of tobacco while leaving no harmful residues.[324g] In coffee and tomato, it serves to repel red ants, and controls many soil insects and nematodes.[152x] The alcohol extracts of both karanja cake and oil have a synergistic effect with carbaryl,[335] and even the water extract of the oil shows powerful activity against tobacco caterpillars.[336] Alcohol extracts of the oil are toxic to fish and show excellent aphicidal activity, and a spray of the oil in soap emulsion is effective against the green bug of coffee.[152x]

Both karanja oil and its water extract are active against cockroaches,[337] and the oil against houseflies.[338] The water-soluble karanjin (page 188/9) appeared to be the main factor in toxicity to the mustard aphid.[231l] In some applications karanja cake was inferior in nematicidal activity to neem and mahua cakes but did control the root-knot of tomato in large doses.[231l] As a synergist for pyrethrum against houseflies, karanja oil was inferior to piperonyl butoxide.[337]

Fresh karanja oil is toxic to mice; acidic, neutral and basic fractions were all toxic, the acidic fraction least so.[339] Expeller cake containing oil is toxic to poultry, but if deoiled, 30 to 40 per cent of the concentrate can be made up of karanja meal for growers and layers,[324h] the only adverse effect noted after 170 days being an enlarged spleen in cockerels.[324h] Even liver function was normal, as judged by serum glutamic oxaloacetate transaminase levels.[340] Small residual oil levels in deoiled meal are not therefore harmful. Alcohol extraction of the meal removes all insecticidal principles as judged by testing against insects, and the nitrogen level in the cake is raised from 3.3 to 4.8 per cent.[335]

D3. KUSUM

The cake has 22 per cent crude protein, a rather low crude fibre content (10 per cent) and high calcium (2.1 per cent) and phosphorus contents, with a moderate ash content (5.3 per cent) but a high level of acid-insoluble ash (3.1 per cent). Several circumstances suggest that the cake is inedible. The powdered seeds are applied to remove maggots from the ulcers and wounds of animals.[152o] Nearly two-thirds of the oil consists of fatty esters of cyanogenic compounds which release hydrogen cyanide on hydrolysis (Section 6.3, page 189). The cake is reported to be used as a fertiliser[152o] and is quite possibly a nematicide. It is also burnt as a fuel.[152o]

D4. NAHOR

The protein content of deoiled kernel meal is 32 per cent, and the phosphorus level is stated to be high.[152n] The presence of three phenolic compounds, consisting of 4-phenylcoumarins, would render the cake inedible (Section 6.3, page 189). There are reports of its use as a fertiliser, and coumarins are known to be active against pathogenic bacteria.[152n]

.D5. UNDI

The presence in the meal of *Calophyllum inophyllum* of four 4-phenylcoumarins (Section 6.3, page 190) would again condemn this meal to non-edible use as a fertiliser, despite its protein content of 29 per cent, and high percentages of calcium (CaO 1.5), phosphorus (P_2O_5 2.0) and potassium (K_2O 1.5).[152a,231j]

D6. RAYANA

There are no details of the cake of *Amoora rohituka*, but the presence in the oil of a high proportion of bitter resins (Section 10.2 B, page 308) would suggest its non-edibility.

E1. MAHUA

Though mahua oil is edible even in crude unrefined form, the cake is not. The seed coat carries as much as 20 per cent of the antioxidants dehydroquercetin and quercetin. The kernels, and hence the meal, have 6 to 8 per cent of a toxic saponin called mowrin (really a mixture, Section 6.3, page 190), about 1.2 per cent of tannin, 8 per cent of crude fibre, high levels of phosphatides (6 per cent) and soluble sugars (11 per cent) and at least two enzymes, sapogenase and glycosidase.[231a,247b]

The 16 per cent protein present in mahua cake nitrifies slowly, and some 60 per cent (against a usual figure of 15 per cent) does not nitrify at all. Mahua cake is applied on the field six months before sowing either alone, or mixed with other oilcakes or nitrogen inorganics. It is particularly valued for paddy, sugar, tea, coffee and unirrigated kharif crops. Keeping the cake before use for eight months in pits mixed with soil, sawdust, bagasse or charcoal is also beneficial.

The toxic quality of mahua cake has long been exploited in India.[152g] It is sprinkled on lawns and golf greens to rid them of earthworms. It is a common practice to clear fish ponds before they are restocked by putting in mahua cake, the old fish float to the top by asphyxiation and can be collected and eaten; and thereafter the cake fertilises an excellent growth of vegetative food for the newly-introduced stock.

The toxicity is due to the saponin which is an extremely powerful surfactant. Steeping the cake in water for two hours, with vigorous stirring for 10 minutes, causes a foam to rise to the surface: after repeating this six to eight times, the foam becomes yellow and oily, which is an indication that the saponin has been removed.[341] Such leached meal supports the growth of calves and keeps them in positive nitrogen balance. Even untreated mahua cake at 50 per cent level has apparently been employed as a maintenance ration for castrated buffalo bulls.[341]

Rats fed mahua meal die in a month as a combined result of starvation and toxicity. Isolated mowrin tested on mice showed the following toxicities expressed per kg bodyweight: oral 1 g, interperitoneal 15 to 20 mg, and intravenous 20 mg.[231a] Massive haemolysis and sloughing of the intestinal mucosa were attributed to the powerful surfactant activity. The saponins can be resolved (Section 6.3, page 190) into the sugar (a mixture of glucose, arabinose, xylose and rhamnose) and the aglycone (protobassic acid, a triterpene alcohol-acid) by refluxing the meal for three hours with 4 vols of 2 per cent hydrochloric acid, cooling, neutralising with sodium hydroxide and drying.[231a] The meal so treated is not toxic to rats at 30 per cent level even on prolonged feeding, and supports normal growth of 1-day old chicks. A simple method of hydrolysing mowrin is by the agency of the enzyme sapogenase which is already present, but this requires keeping the meal wet for two weeks, with the attendant danger of fungal attack.[231a]

The nutritional value of mahua protein is poor, with a low level of lysine, and really low contents of cystine, methionine and tryptophan (Table 21).

F1. KHAKAN-PILU

Khakan whole seed meal has 27 per cent protein and a high crude fibre level of 17 per cent.[152l] Though it is stated to be suitable for use as a livestock feed,[152l] this must be accepted with caution. The oil carries dibenzyl urea and benzyl thiourea in the unsaponifiables, and the cake has a glucosinolate called trapaeolin which hydrolyses to benzyl isothiocyanate (Section 6.3, page 191 and Section 10.2 B, page 308). Possibly the goitrogenic effect of khakan meal when used as a foodstuff has been overlooked in short-term studies. The cake is a valued fertiliser for tobacco.[152l] The amino-acid quality (Table 21) is good, with lysine 5.5 per cent, and methionine plus cystine 5.8 per cent, being exceptionally high.

F3. CHIRANDI

The meal from whole seed has 24 per cent protein, but little else is known about it. The nature of the oil, with its black colour, strong aromatic odour and disagreeable taste,[152q] do not augur well for edibility of the meal.

11.4 Oilcakes that are Inedible: Second Group

Table 24 lists oilcakes derived from various oilseeds of Groups G, H, I and J, which are inedible because unusual constituents reside in either the residual oil or the cake.

OILCAKES WITH INEDIBLE RESIDUAL OILS

The unnatural constituents of residual oils in oilcakes would be more relevant in expeller cakes than in solvent meals almost free of oil. They are of several types (see also p. 311 to 314 under respective oils).

1) Cyclopentene fatty acids occur in G1. MAROTI oil, and have strong physiological activity.

2) Cyclopropene fatty acids have many physiological effects (see Section 6.3, page 192) and occur in several oils: G3. PINARI has 59 per cent, I2. SIMUL 16 per cent and I3. KAPOK 12 per cent, accompanied by 1 per cent of cyclopropane fatty acids.

3) Epoxy acids are suspected of cocarcinogenic effects.[342] They occur in H4. SOMRAJI oil with 78 per cent, and H5. ARGEMONE oil with 2 per cent. The latter oil also carries 1.1 per cent of hydroxy and 1 per cent of mixed keto acids, the latter being a suspected potentiator of the alkaloid sanguinarine in inducing epidemic dropsy (Section 6.3, page 194).

4) A conjugated triene, hydroxy acid, kamlolenic makes up 72 per cent of G2. KAMALA seed oil, and polymerises *in situ* to yield a friable crumbly meal.

5) Sesquiterpene alcohols, esterified with acetic, benzoic, nicotinic and furoic acids, make up 7 per cent of G4. MALKANGUNI oil.

Toxic resins are present to the extent of 2 per cent in H4. SOMRAJI oil, and 5.8 per cent in J8. SITAPHAL oil. In consequence, unrefined sitaphal seed oil, as such and in admixture with neem oil, has exceptional value as a spray against several rice field pests.[327j,327t]

OILCAKES WITH TOXIC CONSTITUENTS IN THE MEAL

A toxic protein is present in G1. MAROTI cake.

Two alkaloids, celastrine and paniculatine, have been recorded in the cake of G4. MALKANGUNI.

Two toxalbumins, curcasin and curcin, as well as a resin with purgative properties, have been found in the meal of H1. RATANJYOTI.

A narcotic, as well as heat-stable antinutritional factors, occur in the meal of I4. BAHEDA.

Table 24. Oilcakes derived from processing oilseeds of Groups G, H, I and J: all oilcakes inedible[a,b]

Oilcake derived from seed of	From whole seed W, or kernel K, by expelling E or solvent extraction S	Protein %	Crude fibre %	Ash			Unusual constituents in oil and cake
				Total %	Ca %	P %	
GI. Maroti[239]	K/E	43	—	—	—	0.9	Oil: 88-92% cyclopentene fatty acids Cake: Polymerised oil, spontaneous combustion, toxic protein
G2. Kamala[152d]	W/E	48	6.6	7.0	—	0.75	Oil: 72% conj. triene hydroxy fatty acid, polymerises spontaneously Cake: Crumbly consistency
G3. Pinari	K/E	No details available regarding compsition					Oil: 59% cyclopropene fatty acids
G4. Malkanguni	W/E	No details available regarding composition					Oil: 70% of sesquiterpene alcohols esterified with acetic, benzoic, nicotinic and furoic acids Cake: Alkaloids celastrine and paniculatine
H1. Ratanjyoti[192]	K/S	38	—	—	—	—	Cake: Purgative resin; two toxalbumins curcasin and curcin
H4. Somraji		No details available regarding composition					Oil: 78% epoxy acid, 2%, bitter resin acid
H5. Argemone[152d']	W/E	25	—	—	—	—	Oil: Fatty acids: 2% epoxy, 1.1% hydroxy, 1% keto (three entities): alkaloid sanguinarine

I2. Simul[182g]	W/E	37	20	6.7	—	—	Oil:	16% cyclopropene
I3. Kapok[182h]	W/E	26	23	6.1	—	1.6	Oil:	12% cyclopropene, 1% cyclopropane
I4. Baheda[280]	K/S[c]	55	—	8	0.3	0.5	Cake:	Unpalatable, narcotic present, heat-stable anti-nutritional factors
I5. Palas[280]	W/E	24	5	4.5[d]	—	—	Cake:	Strong disagreeable odour, toxins, hydrocyanic acid
J8. Sitaphal[202,203,204]	K/S	30	—	5.4	—	—	Oil:	5.8% toxic resin
							Cake:	Non-toxic

[a]References given for individual oilcakes are found in the general reference list to Part C
[b]See Chapter 10 for details of oils
[c]Values calculated from those for kernels
[d]Acid-insoluble ash 0.15%

Toxins and hydrocyanic acid have been noted in the cake of I5. PALAS.

11.5 Oilcakes of Uncertain Edibility

Table 25 (p. 334) lists Indian oilcakes which may perhaps be edible, and Table 26 (p. 336) lists those that are perhaps inedible on the strength of existing evidence (see also Sections 6.3, 10.3 and 10.4 under respective oils).

Oilcakes That may be Edible

E2. SAL meal is a commercial tonnage commodity of limited edibility. Its high content of starch (30 to 36 per cent) and reducing sugars (8.5 per cent) make it useful as an animal feed.[321k] The protein content (8 per cent) is low, but the protein is of good quality, with high percentage contents of lysine (5.7 per cent) and threonine (7.8 per cent), and a moderate level of total S-amino acids (3.9 per cent). Its drawbacks lie in a high content of tannins (6 to 12 per cent) and of acid-insoluble ash (2 per cent). Tannins have an astringent taste, and complex with dietary proteins to cause animal growth retardation. Longer-range effects are liver necrosis and fatty degeneration. For larger animals, tannins only exhibit their toxicity slowly: the effects can also be overcome by including larger quantities of protein in the feed, but this is an expensive alternative. Giving untreated sal meal to laying hens causes a depression in egg production and a greenish discolouration of the yolk. Addition of 10 ppm of iron, say as 0.1 per cent of ferrous sulphate to each 10 per cent of sal meal used in the feed, can counteract this effect.[330]

Treatment of sal meal with ammonia (use of pressure is not essential but hastens the process) has been shown to depolymerise the tannins and to alter their nature so that they cease to tie up proteins any more.[231k] No growth-retardation was observed when the treated meal was fed to rats even at a 60 per cent level, and no untoward effects were seen in laying hens. Ammoniation caused moreover a 3 per cent weight gain in the meal in the form of non-protein nitrogen, which was fully available to animals.

In practice, it has been found more practical to employ untreated sal meal at a 5 per cent level in poultry rations and at a 15 per cent in cattle rations without ill-effect.

Another product that has achieved commercial use in compounded animal feeds is the solvent meal of J1. MANGOKERNEL. This is essentially as a supplier of starch-based energy since the protein content is only 6 per cent; percentages of crude fibre (4.5) and total ash (3.6) are both low. The tannins present appear to be inoffensive.

The edibility suggested for the meals of two *Garcinia* species, E4. KOKUM and E5. TAMAL is conjectural. Kokum cake has a sour taste, perhaps from hydroxycitric acid, which is present in the fruit pulp.

The meal of H3. HURHUR, the dog or wild mustard *Cleome icosandra*, shows a high content of crude fibre and acid-insoluble ash, which seed

dehulling would doubtless reduce. This was true of the seed meals of both the J3. WATERMELON and J4. MUSK MELON, where dehulling dramatically reduced crude fibre levels.[195,196] Musk melon flour had about 34 per cent protein, with low levels of lysine and S-amino acids (Table 21). It had only a slight elevating effect on the PER of wheat (2.25 cf. 1.92) in 20 per cent admixture.[195A] The proteins of I6. TEAK were found to be well to lerated by rats.[342A]

The kernels or whole seeds of several materials listed in Table 23 are easten on a domestic scale: I7. TAMARIND, J3. WATERMELON, J4. MUSK MELON, J11. KAPITTHA, K1. AMBADI, K2. OKRA, K3. TOMATO and K4. CHILLI. Dehulling would reduce crude fibre levels. Total ash contents are within acceptable limits of 4 to 7 per cent. High dietary fibre[292b] and heat-labile antinutritional factors (for example, trypsin inhibitors) were shown to hinder protein utilisation in K2. OKRA seed meal, despite a high protein level,[288A] a high lysine content and good protein quality.[343] The same was also true of K3. TOMATO SEED meal, the PER of which was only 0.81 despite a high lysine level.[355b]

OILCAKES THAT ARE PERHAPS INEDIBLE

E3. DHUPA cake is very hard and unpalatable to cattle.[152b] When the kernels were boiled with water in iron vats, the liquid turned violet or dark brown, and when dumped killed grass and plant life, suggesting the presence of phenolics.[167] Indeed its use as a weed-poison has been suggested.[165] Protein content is only 6.7 per cent.

E6. PHULWARA cake has an exceptionally high tannin content of 16 per cent, besides saponins and 2 per cent of flavonoids. It is used as a worm killer on lawns, as a fish poison and as an insecticide.[152a,] Saponins also occur in J2. THUMBA oilcake (which also carries a glycoside and an alkaloid)[344] and in J9. SAPOTA cake.[152k] J11. GRAPESEED meal has tannins, H2. GOKHRU meal alkaloids[345] and F2. PISA meal aromatic volatile esters. Both J5. LIME seed meal and J6. SWEET ORANGE seed meal carry bitter constituents.

J7. PAPAYA seed meal carries both a glycoside, termed caricin,[152b,] and a glucosinolate, glucotrapaeolin, which on enzyme hydrolysis in the presence of water yields benzyl isothiocyanate with a pungent odour.[346]

Table 25. Oilcakes derived from processing oilseeds of Groups E, H, I, J and K: edibility uncertain, but perhaps edible[a]

Oilcake derived from seed of	From whole seed W orkernel K, by expelling E or solvent extraction S	Protein %	Crude fibre %	Ash		Features of cake		
				Total %	Acid-insol. %	Protein	Crude fibre	Others
1	2	3	4	5	6	7	8	9
E2. Sal[65]	K/S	12	6	4[b,i]	2	L	L	Tannins 6-12%, ellagic acid 0.15%
E4. Kokum[230]	K/E	17				L		Sour taste
E5. Tamal		No details available regarding composition						Seed coat constituents cathartic and anti-bacterial
H3. Hurhur[184]	W/E	18	41	6.5	2.3	L	VH	Crude fibre and acid-insoluble ash high
I1. Akra[182,f]	—[e]	35	40	8		H	VH	
I6. Teak[187,250,h]	K/E	60	4.5	– c.12		VH	L	Total ash high
I7. Tamarind[188]	K/E	19	1.1	3.4	0.3	L	L	
J1. Mango kernel[256]	K/S	6	4.5	3.6		VH	L	Tannins
J3. Watermelon[195,214]	W/E	28	39	5	nil	M	VH	
-do-	K/S	51	4	9	0.1	VH	L	Dehulling reduces crude fibre
J4. Musk melon[195h,196,214]	W/E	24	36	14	4.3	M	VH	Total ash high
-do-	K/S	66	3	9	nil	VH	L	Dehulling reduces crude fibre

J11. Kapittha[205]	W/E[c]	40	27	6		H	H	
K1. Ambadi[152m,206,357]	K/E	28	18	7	0.2	M	H	High P_2O_5 (2.24%) and K_2O (2.02%)
K2. Okra[152e,228d]	—[c]	23	25			M	H	
K3. Tomato[207]	W/E	40	22	6.2[b ii]		H	H	
K4. Chilli[208]	—[c]	30	25	4.3		M	H	

[a]References given for individual oilcakes are found in the general reference list to Part C

[b]Ca and P %: (*i*) 0.21 and 0.17; (*ii*) 0.26 and 0.90

[c]Calculated from seed values

[d]VH—Very High, H—High, M—Moderate, L—Low

Table 26. Oilcakes derived from processing oilseeds of Groups E, F, H and J: edibility uncertain, but perhaps inedible[a]

Oilcake derived from seed of	From whole seed W or kernel K, by expelling E or solvent extraction S	Protein %	Crude fibre %	Ash: Total %	Ash: Acid-insol %	Features of cake[c]: Protein	Features of cake[c]: Crude fibre	Features of cake[c]: Others
E3. Dhupa[152b,165,324a]	K/E	61	9	6.9	3.7[b]	VH	M	Cake hard, unpalatable to cattle, contains resin
E6. Phulwara[152a,168a,358]	K/E	39	9	6.2		H	M	Tannins 16%, saponins, 2% flavonoids in seed coat
F2. Pisa[270]								Volatile esters
H2. Gokhru[185,346]		23	26	8.4	2.4	M	H	Alkaloids
J2. Thumba[240,344]	W/E	24	45	—		M	VH	Glycoside, saponin, alkaloid, phytosterolin
J5. Lime[197]	W/E	30	21	8		M	H	Bitter taste
J6. Sweet orange[197,198]	K/E	24	13	7	0.35	M	M	Bitter taste
J7. Papaya[152r,350,360]		No details available regarding composition						Glucotrapaeolin, a glucosinolate, and caricin, a glycoside
J9. Sapota[152k]		No details available regarding composition						Saponin 1%, bitter sapotinin 0.08%
J11. Grape[274]	W/E	14	43			L	VH	Tannins

[a]References given for individual oilcakes are found in the general reference list to Part C
[b]Ca 0.29 and P 0.78%
[c]VH—Very high, H—High, M—Moderate, L—Low

CHAPTER 12

Oilseed Processing in the Twentieth Century

For centuries ghanis were the major means of obtaining oil from oilseeds in India. It is only at the beginning of the present century that any alternative was even possible, and since then there has been a gradual historical shift from animal-driven ghanis to other forms of oil-expression like rotaries, hand-screw presses, hydraulic presses, expellers and solvent plants. This chapter will attempt to trace these movements quantitatively.

12.1 Oil Production Around 1900

Ghanis

One account of the vegetable oil industry in India states that at the turn of the century there were between 400,000 and 500,000 bullock-driven ghanis in the country.[361] This may also be deduced indirectly. In 1900, the area under oilseeds was estimated at 7.5 million acres (this is stated to be only a partial estimate),[51l] in 1907 the figure was placed at 13.5 million acres,[51l] and in 1901, a figure of exactly 12 million acres is recorded,[362] which we may accept. At an average yield of oilseeds at the time of 450 lb/acre, this would have meant 2.5 million tonnes of oilseeds. The average crushing capacity of a ghani, from a long list recording their outputs, comes to 35 kg/day,[42f] which would mean that crushing of the quantity of oilseeds noted would have needed some 250,000 ghanis, assuming total capacity utilisation. Since this is most unlikely, the number of ghanis at a 50 to 60 per cent utilisation could well have between 400,000 and 500,000 at the turn of the century. These ghanis would have turned out about 800,000 tonnes of oil about 1900.

Power-driven Units

About this time, to quote, "in some parts of the country small 'chucker mills' powered by oil engines began to spread after 1900".[363] Chucker is an anglicisation of chakra or wheel, from which was derived also the word chekku by which the ghani is called in south India (see page 209), and

it stands here for the power-driven rotary which has a toothed wheel at the base. Rotaries were thus the first oil-crushing devices that used non-animal or human labour.

In 1904, there were some 212 modern oil mills, employing in all 5,084 persons;[51j] 100 of these employed less than 25 persons, and the rest more than this number.[51j] Of these oil mills, 75 were in Bengal, employing about 40 persons each, and using 35,000 tonnes of seed, which meant an average daily capacity of about 16 tonnes. Madras had 24, employing some 70 persons each, and Bombay only 2, with 113 persons apiece. These were the three large Presidencies of British India of the time.

In 1903, 11 of these were stated to have been worked by steam,[51j] and elsewhere also, 'English steam-presses' are mentioned.[10d] In 1890 it was mentioned that mills of European pattern were tried but abandoned since they were not found remunerative.[10d] These were perhaps steam-driven commercial hydraulic presses (Section 8.1, p. 244), but the main crushing units in these oil mills were rotaries.

The total capacity of the 112 oil mills employing more than 25 persons, extrapolating from the figures for the 75 oil mills of Bengal,[51j] was about 52,000 tonnes of seed, yielding some 17,000 tonnes of oil. The remaining 100 smaller units in 1904, at a rough estimate, must have produced some 8,000 tonnes of oil.

Thus in 1904, production of oil in India constituted about 800,000 tonnes from ghanis and 25,000 tonnes from industrial units. The quantities of individual oils and oilcakes in 1904 were of the following orders of magnitude:[364]

	Oil	Oilcakes
Sesame	162,000	253,000
Rape-mustard	271,000	479,000
Coconut	100,000	58,000
Linseed	120,000	240,000
Castor	48,000	72,000
Groundnut	100,000	150,000
Total	801,000	1,252,000

12.2 Oil Production in the Forties

Ghanis

In 1951, a careful estimate[42f] showed that some 445,000 ghanis were working in India, a figure to which we shall return. In 1900, as seen, this was also the estimated number. It is reasonable to assume then that some 450,000 ghanis were working in India in the early forties producing, as in earlier times, some 800,000 tonnes of oil.

POWER-DRIVEN UNITS

A book published in 1938 describes three types of equipment available in India.[365] The first is an improved rotary ghani made by Volkart Bros., Bombay. Then come expellers of French, German and English make like Krupp's Standard, Sohler type; that of F. Muller, Esslungen; that of the Anglo-American Oil Mill Machinery Co. of England (ranging in capacity from 10 tonnes to 1000 tonnes); and 'the latest', which was V.D. Anderson's Super-Duo with a daily capacity of 8 to 13 tonnes that left only 5 per cent residual oil in cake. Finally Hydraulic Press Plants of F. Muller are stated to be supplied by Volkart Bros., Bombay.

A linseed marketing report of 1939 features a map showing the locations of power oil mills in India.[52] While not very clear, counting of the open circles and dark squares and of some figures appears to indicate that there were about 500 power-driven oil mills working on various oilseeds in India. These used rotaries and expellers, and may also have had screw presses worked by power. The choice of the units appears to have depended (as it still does) on the particular oilseed being crushed in the region. Thus hand-screw presses heated with fire from below are mentioned for castorseed crushing, rotaries for copra and rape-mustard seeds, and expellers for linseed and groundnut. Hydraulic presses, which were all the rage in the twenties and the thirties (Section 8.1, page 244), are hardly ever mentioned in the several marketing reports of the decade, and seem to have faded into oblivion.

Sesame and niger seeds appeared to have been crushed almost totally in ghanis.[63] Under rape-mustard seeds, all types of processing devices are mentioned, namely chappas, ghains, rotaries, expellers and even hydraulic presses (these are noted as being 'rarely used' for these seeds).[41] In areas like Punjab, where extreme pungency in the oil is not greatly in demand, two-thirds of all rape-mustard seeds were processed in expellers (1942), but rotary crushing, backed up by expeller extraction of part of the residual oil, appeared to have been the favoured procedure in the United Provinces and Bihar, which together accounted for 85 per cent of the total oil produced from this commodity. Such a sequence is still the practice today.

The coconut marketing report (1944) refers to 111 power-driven oil mills with 1,400 rotaries, besides 35 expellers.[38] About 35,000 ghanis also crushed copra.

In describing the processing of linseed (1939), a distinction was made between 600 and 700 expellers and 123 power mills;[52] the latter must therefore only refer to batteries of rotaries.

Castor seed processing in 1948 was still effected by some 800 hand-screw presses, besides 34 "large power-driven oil mills",[74] meaning almost certainly expellers in this instance.

Finally groundnut processing in 1941 is fully outlined: 300 hand-screw presses, 2,100 rotaries and 650 expellers dealt with this crop.[39a]

The total area under oilseeds in India in million ha was stated to be 8.62 in 1936 to 1938, 8.83 during 1941 to 1945 and 9.88 between 1946

and 1950.[364] Table 27 shows the quantities of seven major oilseeds produced in India during the decade around 1940, and the quantities of

Table 27. Production around 1940 of seven major oilseeds in India, and of oils and oilcakes derived from them[a]

All figures in thousand tonnes

Oil-bearing material	Year	Production of		
		Seed	Oil	Oilcake
Sesame[68]	1939-50 average	450	119	186
Rape-mustard[41]	1934-39 average	990	345	605
Coconut (copra)[30]	1934-39 average	200	126	73
Linseed[63]	1936-37	469[b]	66	131
Castor[74]	1946	212	62	92
Niger[68]	1946-49 average	72	15	37
Groundnut[30]	1933-38 average	2,822[b]	336	504

[a]References shown for individual materials are found in the general reference list to Part C(p. 346)
[b]Considerable seed exports

oil and oilcakes derived by processing these oilseeds. Except for the groundnut, the areas under the other oilseeds, and hence their production, hardly changed between 1940 and 1950.[364] Total acreages under oilseeds averaged 8.83 and 9.88 million ha during the periods 1941 to 1945 and 1946 to 1950. The average figures in million ha for various oilseeds during 1941 to 1945, and 1945 to 1950, stood as follows: sesame 1.615 and 1.863, rape-mustard 1.727 and 1.740, and castor 0.546 and 0.566. Linseed was grown on 1.337 to 1.580 million ha through the entire half century 1901 to 1953, and coconut oil in India between 1934 and 1953 was produced within the limits of 1.21 and 1.50 million tonnes annually.[364] Only for the groundnut has area really shown an increase, from an average of 1.478 million ha in the decade 1921 to 1930, to 2.855 million ha during 1931 to 1940, and further to 3.782 million in 1941 to 1950, the corresponding production rising from 1.511 to 2.741 and 3.312 million tonnes respectively. Hence taking the 1933 to 1938 average figure for groundnut as 2.822 million tonnes (of which 39.4 per cent was exported), the production of oil from the seven materials listed in Table 27 was of the order of

1.1 million tonnes during the quinquennium 1933 to 1938.[364] The major oils were rape-mustard, groundnut, coconut and sesame in that order. The corresponding production of total oilcakes was about 1.6 million tonnes.

12.3 Oilseed Processing in the Fifties

Production from Ghanis and Oil Mills

Eastimates of the number of ghanis in India were made by the Livestock Census in India during the years 1951 and 1956, with the following outcome:[42f]

		1951	1956
Capacity below 5 kg	..	242,430	211,663
Capacity above 5 kg	..	204,006	95,559
Total ghanis	..	445,436	307,222
States not enumerated	..	Bihar, Orissa, Jammu and Kashmir, Manipur	Manipur

About the same time, the percentage proportion of each oilseed crushed in ghanis, as contrasted with oil mills, was as follows:[42f] sesame 83, rape-mustard 37, coconut 20, linseed 30, castor negligible and groundnut 20 respectively. From the quantities of total oils produced from each of these oilseeds,[42g] the amounts of ghani and mill oils work out as follows:

			Ghani oil	Mill-produced oil
			thousand tonnes	
Sesame	..	..	145	36
Rape-mustard	..	..	106	180
Coconut	..	..	26	102
Linseed	..	..	34	78
Castor	..	..	—	38
Groundnut	..	..	185	739
Total	..	..	596	1173

Thus these seven major oilseeds yielded some 1,669 million tonnes of oil, and a corresponding 2.45 million tonnes of oilcake in 1954. Oilseeds like the niger, safflower and mahua are not included in this computation; they were totally processed in ghanis.

NATURE OF CRUSHING MACHINERY

The Oilseeds Crushing Enquiry Committee estimated in its 1956 report that the number of oil mills in the Indian Union around that time was 8,201.[42f] The number of units of various kinds in these oil mills, and their estimated annual crushing capacity, was as follows : 3,475 expellers with a total annual capacity of about 1,867 million tonnes of oilseeds; 153 hydraulic presses, capacity 69,000 tonnes; 16,432 rotary ghanis, capacity 851,000 tonnes; and 4,886 powered ghanis of other types with an annual capacity of 253,000 tonnes, giving a total crushing capacity of 3.04 million tonnes of oilseeds annually.

Actual production of the five major oilseeds in the country (this excludes the coconut) in 1954 was 5.785 million tonnes. Allowing for seed used for sowing, edible purposes and export, which averaged 9.70, 9.34 and 0.56 per cent of the total respectively,[42g] and taking into account the existence of 350,000 ghanis, the processing capacity in the power sector was fairly matched with oilseed production.

12.4 Oilseed Processing in 1966-67

OILSEED AVAILABILITY

In 1966-67, the total quantity of six major Indian oilseeds produced was 3.572 million tonnes.[366] This included sesame, cottonseeds, rape-mustard, linseed, castor and groundnut, but omitted copra, safflower and niger. The quantities of seed retained by producers domestically for sowing, edible use and so on was stated to be (as percentages): sesame 22.3, rape-mustard 8.1, linseed 11.3, castor 6 and groundnut 18.5.

OILSEED PROCESSING

The quantity of each oilseed crushed by ghanis had come down further from the percentages of the previous decade, now being: sesame 26, cottonseed nil, rape-mustard 19, copra nil, linseed 40, groundnut 7 and other oilseeds 20.[366]

The production system now consisted of: ghanis 231,000, oil mills 12,483; rotaries 30,420 and solvent-extraction plants 93.[366] The numbers of expellers installed in oil mills showed the following distribution in terms of daily capacity: 1 to 5 tonnes, 7,759; 5 to 10 tonnes, 3,330; and above 10 tonnes 1,394. The rotaries had an average capacity of 250 kg/day, which is over seven times that of an average ghani.

The capacity utilisation of rotaries and expellers was stated to average just 18 per cent (range 9 to 22 per cent), and that of solvent plants 46 per cent.[366] Processing capacities had clearly outstripped raw material production.

12.5 Oilseed Processing Scenario for 1983-84

PRODUCTION AND PROCESSING

In 1983-84, it was estimated that the oilseed processing system consisted

of about 150,000 ghanis, of which 11,000 were of improved and powered types, some 20,000 expellers and 305 solvent-extraction plants.[65] Table 28 shows processing details of these units.

Table 28: Oilseed processing scenario 1983-84[a]

		Ghanis	Expellers	Solvent plants
No. of units		c. 150,000	c. 20,000	305
Production:				
Oil	th.t	210	3,444	389
Oilcake	th.t	319	5,421	2,822
Raw material handled:				
Annual	th.t	500	9,600	3,300
Daily		12 kg	1.6 t	37 t
Usual daily capacity		35 kg	5 t	110 t
Capacity utilisation, %		34	33	34

[a]K.T. Achaya, unpublished

It is clear that units in India are of small processing capacity, averaging about 35 kg daily for ghanis, 5 tonnes for expellers and 110 tonnes for solvent plants. Despite this, utilisation is barely a third of capacity for all types of units, reflecting an acute scarcity of raw material.

INDIVIDUAL OILSEEDS

Table 29 pictures the production of each oilseed in India and its processing during 1983-84.[65] Only five oilseeds, sesame, rape-mustard, copra, safflower and groundnuts, are now processed in ghanis to any significant degree, and the total ghani oil produced represents barely 5 per cent of the total. Only for the safflower does ghani oil constitute 39 per cent, and for sesame oil 24 per cent, of the total oil produced from each seed. Expeller oil is by far the most important. Groundnut oil and rape-mustard contribute 70 per cent to the total expeller oil pool, and copra, cottonseed and castor oils some 5 per cent each. The solvent system is made up of two major oils, those of the ricebran and groundnut (43 and 19 per cent), other contributors being soybean, cottonseed and sal seed oils (11.7 and 3 per cent respectively).

Neem and mahua oils derived by solvent-extraction constituted 10,957 and 4,566 tonnes in 1983-84, and karanja and kusum oils 918 and 433 tonnes respectively. Oilseeds shown as 'Others' in Table 29 were grouped together, but subsequently figures were to be had for a further number of individual non-traditional oilseeds processed by solvent extraction.[65] The

Table 29. Computed production of various types of oil and cake from each oilseed in India, 1983-84[a]

All figures in tonnes

Oil-bearing material		Oil			Cake		
Name	Production	Ghani	Expeller	Solvent	Ghani	Expeller	Solvent
Sesame	618,000	47,000	146,433	466	65,250	213,266	5,662
Cottonseed	440,000	—	154,000	15,694	—	1,246,000	190,693
Rape-mustard	2,566,000	49,250	762,444	7,965	106,250	1,415,779	96,780
Copra	360,000	2,500	222,074	2,370	2,750	100,210	28,797
Linseed	440,000	—	130,680	976	—	247,990	11,859
Castor	407,000	—	141,705	3,698	—	191,108	44,933
Nigerseed	175,000	—	44,100	707	—	103,715	8,591
Safflower	469,000	68,250	98,884	6,278	78,500	62,326	76,282
Groundnut	5,099,000	43,250	1,616,434	43,231	66,250	1,832,447	525,286
Soybean	412,000	—	—	58,083	—	—	303,597
Sunflower	272,000	—	90,576	11,171	—	68,293	71,323
Ricebran	1,430,000	—	—	202,087	—	—	1,212,522
Neem	—	—	—	10,957	—	—	62,600
Karanja	—	—	—	918	—	—	7,895
Kusum	—	—	—	433	—	—	2,866
Mahua	—	—	26,806	4,566	—	Nil	55,480
Sal seed	—	—	—	15,315	—	—	87,499
Mango kernel	—	—	—	239	—	—	2,507
Others[a]	—	—	—	3,473	—	—	26,837
Total, th.t		210	3,444	389	319	5,421	2,822
Totals of oils and cakes, th.t			4,043			8,562	

[a]Non-traditional oilseeds, grouped as "Others", were first named individually only in 1984-85 (see Text)

quantities of these solvent-extracted materials in 1984-85 are shown below:

Oil-bearing material	Oil, tonnes	Oilcake, tonnes
Tobacco	138	1,246
Spent coffee	14	224
Akra	30	462
Kapok	466	970
Palas	92	888
Thumba	156	1,535
Ambadi	20	535
Miscellaneous	1,073	5,136

Oilseeds gathered by voluntary agencies appear to escape the official computations. These oilseeds are processed not in ghanis but in expellers by contract. The derived oils are used for soap-making, and the oil-cakes find local use as feed or fertiliser. It is estimated that some 10,000 tonnes of oil and 30,000 tonnes of expeller cake are thus generated.[65]

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GLOSSARY OF INDIAN WORDS

Definitions have been kept brief

(Reference to the page number(s) indicated will furnish further information in context)

abhaya : inspiring fear (142)
achar : pickle (199)
achchellu : niger, *Guizotia abyssinica* (46)
ad : to eat (53)
adai : fried rice-pulse snack (158)
adhaka : a weight (13, 23)
adhasisi : *Xanthium strumarium* (107)
aditya : commission agent (29)
agashi : linseed (61)
aishi : linseed (61)
akanda : *Calotropis gigantea* (109)
akra : *Calotropis* spp. (109)
al : root of *Morinda citrifolia* (170)
alarka : *Calotropis procera* (109)
alshi : linseed (61)
alu : any tuber, potato (81)
amal-bid : an acidic citrus (?) (114)
amaltas : *Cassia fistula* (164)
aman : type of rice (80)
ambadi : *Hibiscus cannabinus* (118)
amla : *Emblica officialis* (159)
amli : tamarind (146)
amra : mango (112)
amrataka : wild mango (112)
amrita : divine nectar (136)
angara polika : stuffed wheat snack (158)
Anjuvanam : a guild (19)
anna : cultivated foods (43)
apupa : deep-fried snack (157)
argya : libations (142)
arhatiya : commission agent (29)
arishta : *Xanthium strumarium* (108, 177)
arisi : rice (79)
arjuna : *Terminalia arjuna* (183)
arka : *Calotropis gigantea* (109)
arkaparna : *Calotropis* spp. (109)
artha : craft (14)
ashtami : birth (141)
ashtibhija : cottonseed (12)
asu : type of rice (79)
asuri : stalk of black mustard (53)
asvakarna : *Shorea robusta* (12)
asvamedha : horse sacrifice (140)
asvatta : *Ficus religiosa* (138)
atasi : linseed (61)
atmagupta : *Mucura prurita* (183)
aukhali : ghani mortar (211)
avalu : mustard (155)
avel : oil from fresh coconut (239)
avleh : medicated halwa (177)
ayamana : a weight (23)
ayamani : the king's balance (23)
ayurveda : Hindu medicine (171)
baberang : *Embelia ribes* (177)
babul : *Acacia arabica* (211)
baghaar : extracting species in hot oil (161)
baheda : *Terminalia belerica* (110)
baira : *Terminalia belerica* (110)
baja : red mustard seeds (142)
bajra : *Pennisetum yphoideum* (63, 232)
bandana : printed cloth (170)
banga : variety of sarson (q v.) (31)
bania : small tradesman (36, 92)
baragi : wandering ascetic (136)
bara-jouar : maize (83)
barilla : calcination process (165)

barra : mixed sarson (q.v.) (31)
bartundi : *Morinda citrifolia* (170)
bays : weighmen (37)
berseem : *Trifolium alexandrium* (71)
besan : chickpea flour (165)
bhadritaka : spit-roasted meat (159)
bhaga : a tax (22)
bhakari : baked bread (71)
bhandi : perhaps *Abelmoschus esculentus* (118)
bhangra : *Eclipta prostata* (164)
bharadvaji : wild cotton (47)
bharjita : fried meat (159)
bhat : soyabean (70)
bhatwan : soyabean (70)
bhendi : *Abelmoschus esculentus* (118)
bhilawan : *Semecarpus anacardium* (240)
bhojpat : load beam (212)
bhringaraj taila : medicated oil (163)
bhuiti : safflower (65)
bhuta : seed, rosary bean (83)
bhutta : maize cob (83)
bidi : leaf cigarettes (100)
bijapuraka : *Citrus medica* (114)
bilva : *Aegle marmelos* (146)
bindhu : drop (173)
bodhi : *Ficus religiosa* (135)
bodi : safflower (65)
bodki : safflower (65)
boja : a weight (40)
boma : oilseed probe (29)
brahma-varcas : brilliance, lustre (146)
Brahmi taila : medicated oil (164)
burugu : *Bombax ceiba* (155)

calani : sieve (13)
camana : grain-cleaning operation (13)
candi : a weight (40)
candy : a weight (34)
car-ellu : sesame (45)
chakka : wheel (209)
chakki : millstone (209)
chakra : wheel (207)
chapati : unleavened bread (83)
chappa : plank press (240)
charka : hand roller (50)
chatny : ground moist relish (71)
chattank : a weight (30)
chaulmoogra : *Hydnocarpus kurzii* (221)
chaval : food (79)
chaval-moogri : *Hydnocarpus kurzii* (104)
cheeku : *Manilkara achras* (116)
cheetu killichan-kottai : description of the groundnut (67)
chekku : oil press (376)
chinchapala : tamarind (111)
chirandi : *Litsea glutinosa* (104)
chironji : *Buchanania latifolia* (278)
chitrajiva : castor (61)
chiura : *Diploknema butyracea* (102)
chowdana : system of coconut buying (33)
chowri : fly whisk (19)
chunchala : jute (155)
churna : powdered medication (177)
chuta : mango (112)
copra : desiccated coconut (32)
cohha : coffee (90)

dadiya : leaf cup (146)
dalal : broker (29)
dammar : gum of *Vateriu indica* (100)
danka : sediment (235); outlet plug (211)
danti : *Baliospermum montanum* (164)
darba : *Desmostachys bipinnata* (140)
datheri : argemone (108)
datturi : argemone (108)
devarakadu : god's forest (133)
dhal : split pulse (161)
dhanya : food, rice (79)
dhanyakrt : winnowing fan (13)
dharana : a weight (22, 51)
dharma : duty (14)
dhatu : body humour (171)
dhenki : foot-pounder (80)
dhupa : *Vateria indica* (100)
dosai : fried rice snack (158)
dosha : harmful element (172)

draksha : grapes (116)
dramma : a coin (20)
drona : a weight (23)
duan : *Eruca sativa* (32, 51)
dvija : brahmin (21)

ell : sesame (210)
ellu : sesame (45, 46)
ennai : liquid oil (46, 210)
eranda : castor (61)

farangi-dhatura : *Argemone mexicana* (108)

gajjar : carrot (31)
galbalia : variety of sarson (q.v.) (31)
gana : guild (18)
ganj : market (29)
ganuga : oil press (208)
gari-kalay : soyabean (70)
garudaphal : *Hydnocarpus laurifolia* (104)
gaura-sarshapa : yellow sarson (q.v.) (53)
ghan : one charge on an oil press (208)
ghana(ka) : oil press (208)
ghani : oil press (208)
gharika : gram-based snack (159)
ghasul : a liquid soap (166)
ghatani ; mill (209)
ghatanika : pounding (209)
ghatika : a measure (24)
ghavan : stone mortar (209)
ghee : clarified butter (11, 25)
ghranaka : oil press (208)
ghrta : ghee (q.v.) (157)
ghrtapakvah : fried in clarified butter-fat (158)
ghrtapura : stuffed wheat confection (159)
ghrtavantam : cooked in clarified butterfat (157)
gingelli, gingelly : sesame (25, 45)
giriya : gourd seed mixture (175)
gokhru : *Xanthium strumarium* (107)
gongura : *Hibiscus cannabinus* (155)
gonkuru : *Hibiscus cannabinus* (118)
gowshala : home for aged cows (37)
graishmukha : summer rice (79)
gram : pulse, e.g. redgram (12)
gravan : grinding stone (209)
grishma : a season (11)
guda : uncrystallised brown sugar (43)
guggal : *Commiphora mukul* (183)
gulancha : *Tinospora cordifolia* (183)
guna : attribute of matter (172)
gunny : jute sack (34, 89)
gurellu : niger (64)
guruga : oil press (208)

haimantika : spring rice (79)
haimavati : linseed (60)
halas : *Butea monosperma* (155)
hamal : labourer (37)
harada : *Terminalia chebula* (175)
haralu : castor (155)
hariali : *Cyanodon dactylon* (174)
harir : *Terminalia chebula* (175)
hastikarna : castor (62)
hat : primary market (29)
hayana : rice (79)
hayavana : rice (79)
hemalu : tapioca (81)
hemantha-rithu : spring season (11)
henna : *Lawsonia enermis* (164, 170
homadhanya : sacrificial grain (139)
huchchellu : niger (64)
hul-hul : *Cleome viscosa* (108)
hurhur : *Cleome viscosa* (108)
hur-huria : *Cleome viscosa* (108)

ikat : dyed fabric (170)
ikh : sugarcane (209)
ikshu : sugarcane (153)
imli : tamarind (111)
indrayan : *Citrullus colocynthis* (112)
ingudi : *Balanites aegyptiaca* (21)
ishtadevata : tutelary deity (143)

jaggery : uncrystallised brown sugar (230)
jamba : *Eruca sativa* (51, 232)
jambhiri : citrus fruit (114)

jambu	: *Syzygium cumini* (159)
jangli	: wild (32)
jangli-eranda	: *Jatropha curcas* (107)
jartila	: wild sesame (43)
jataka	: Buddhist tales (9)
jati	: forerunner of caste (18)
jetthaka	: head of guild (17)
jhuta-jhut	: waste silk (89)
jom	: to eat (79)
jon-khar	: potassium carbonate (165)
jonna	: maize (155)
jowar	: *Sorghum vulgare* (232)
juta	: fibre (89)
jyotismati	: *Celastrus paniculatus* (106)
kaccha	: smaller; poorly finished (30)
kachcha	: smaller; poorly finished (30)
kadhai	: frying vessel (161)
kadugu	: *Brassica nigra* (51)
kahapana	: copper coin (18)
kahwa	: coffee (9)
kai	: fruit (56)
kajal	: lamp black (142)
kala	: black (64)
kalam	: pen (40)
kalamasali	: type of rice (80)
kala til	: black sesame (64)
kali	: black (31, 73)
kalinda	: watermelon (113)
kalitur	: black soyabean (73)
kalpadruma	: *Nyctanthes arbor-tristis* (134)
kama	: love (14)
kamala	: *Mallotus philippinensis* (105)
kamela	: *Mallotus philippinensis* (105)
kamila	: *Mallotus philippinensis* (105)
kanaka	: *Butea monosperma* (135)
kanphuti	: *Cleome icosandra* (108)
kantakadruma	: *Bombax ceiba* (109)
kapha	: a body homour (171, 172)
kapi	: peacock (24)
kapila	: *Mallotus philippinensis* (105)
kapittha	: *Limonia acidissima* (117)
kapok	: *Ceiba pentandra* (110)
kapur kachri	: *Hedycum spicatum* (164)
karadi	: safflower (64)
karanja	: *Pongamia pinnata* (93)
karapasa	: cotton (47)
kari	: meat dish (159)
karpasi	: cotton (47)
karshapana	: copper coin (23, 24)
kasara	: a wheat confection (158)
Kashmir-amlika	: *Annona squamosa* (?) (116)
katakarna	: crisp fried snack (159)
kati	: safflower (65)
kayir	: coconut fibre (56)
khadira	: *Ficus benghalensis* (146)
khakan	: *Salvadora* spp. (102)
khal	: oilcake, sugar (208)
khali	: oilcake, sugar (208)
khalya	: threshing ground (13)
khand	: oil press pit (211)
khara pilu	: *Salvadora persica* (102)
kharbuza	: musk melon (113)
khari	: sodium sulphate (166)
kharif	: monsoon crop (7)
kharkhana	: factory (163)
khar sajji	: sodium carbonate (165)
kheer	: sweet rice-milk dish (43)
kimsuka	: *Butea monosperma* (12, 111)
kinbil	: *Mallotus philippinensis* (105)
kino	: exudate of *Butea monosperma* (168)
kokum	: *Garcinia indica* (101)
kolhu	: oil-mill (209)
kolhuka	: oil-mill (209)
kostaki	: *Luffa acutangula* (14)
kothi	: storage jar (30)
kotti	: dry coconuts (33)
kristapachya	: cultivated grains (43)
krsara	: composite rice dish (43)
krsnala	: a weight (22)
kshatriya	: the warrior caste (144)
ksuma	: linseed (60)
kuduba	: a weight (160)
kudumba	: a volume measure (23)
kulu	: food, rice (79)
kumbha	: a volume measure (23)
kunapa	: liquid fertiliser (13)
kuru	: boiled rice (79)

kurchi : *Holarrhena antidysenterica* (177)
kusa : *Desmostachya bipinnata* (140)
kusamra : unidentified oilseed (210)
kusum : *Schleichera oleosa* (96)
kusumą : safflower (64)
kusumbha : safflower (65)
kutela : safflower (65)
kwath : any medicated decoction (177)

laddu : sweet ball (43)
lāl : red (31)
lāl ambadi : *Hibiscus sabdariffa* (118)
lāt : pestle (211)
likya : a weight (22)
lotani : variety of sarson (q.v.) (31)
lothani : carding device (103)
lotni : brown sarson (q.v.) (51)

madar (a) : *Calotropis* spp. (109)
madhu : sweet, honey (99)
madhuka : *Madhuca indica* (99)
madhubani : painting style (146)
madhumestaka : stuffed wheat confection (158)
madhusirsaka : stuffed wheat confection (159)
magbi : a *brassica* (31)
maghi-lahia : brown *toria* (q.v.) (31)
maghra : mixed sarson (31)
magli : toria (q.v.) (51)
mahajana : brahmin dignitary (19, 21)
maharishi : great sage (136)
mahasali : plump rice (80)
mahavrihi : large rice (79)
mahua : *Madhuca indica* (98)
mahendra-varuni : *Citrullus colocynthis* (112)
majja : unidentified oilseed (158)
makka : maize (83)
makki : maize (83)
malkanguni : *Celastrus paniculatus* (106)
manasrava : extra volume (23)
manda : milk confection (162)
mandaka : wheatsnack (158)
mandara : *Calotropis* spp. (109)
mandi : market (29)
mangga : mango (112)
Manigraman : a guild (19)
Manila-kottai : groundnut (67)
mannal-velli-kottai : groundnut (67)
maravetti : *Hydnocarpus laurifolia* (104)
maroti : *Hydnocarpus laurifolia* (104)
markal : volume measure (40)
marsina : linseed (60)
masa : *Vigna mungo* (13)
masha : a weight (22)
masur : *Lens esculenta* (71)
matti : earth (165)
matulunga : *Citrus medica* (114)
maund : a weight (23, 24)
medasaka : *Litsea glutinosa* (104)
meenamasa : mass marriage (151)
mendhi : *Lawsonia enermis* (170)
methi : tethering post (13)
mitha-pat : *Corchorus olitorius* (89)
mitha-pilu : *Salvadora oleoides* (102)
modaka : sweet stuffed confection (148)
mosambi : *Citrus sinensis* (114)
mrdvika : grapes (116)
mudga : *Vigna radiata* (13)
mung : *Phaseolus aureus* (70)
muni : a saint (20)
mura : a fragrant plant (13)
murha : a package (34)
murilia : safflower (65)
musala : pestle (207)
muskani : *Merremia gangetica* (177)
muthel : oil from copra (239)

nadika : leafy edible preparation (89)
nadu : confection (171)
nagakesara : *Mesua ferrea* (96)
nagaranga : the orange (114)
nagarmotha : *Cyperus scariosus* (177)
nageswara : *Mesua ferrea* (96)
nahor : *Mesua ferrea* (96)
naiveddya : food offered to gods (143)
nai : clarified butterfat (46)
naigama : guild (18)

nalita : edible jute leaf dish (89)
nall-ennai : sesame oil (46)
namak : salt (166)
narangi : *Citrus sinensis* (114)
nargil : coconut (57)
narikela : coconut (56)
neem : *Melia indica* (93)
ngai : coconut oil (57)
nimbu : *Citrus aurantifolia* (114)
nirgundi : *Vitex negundo* (173)
nir nangu : *Mesua ferrea* (96)
nisa : turmeric (53)
nisada : a tribe (53)
niu : coconut oil (57)
nīvara : wild rice (80)
niyor : coconut oil (57)
nurai : froth (209)
nuvvulu : sesame oil (46)

odayayāntrika : hydraulic machines (21)
okhli : small mortar (209)
opatna : scented soap (166)

padi : volume measure (40)
pahalika : stuffed wheat preparation (158)
pahadi rai : leafy form of rai (q.v.) (54)
paili : a volume measure (30)
painth : primary market (29)
pak : medicated confection (177)
pakka : ritual food classification (161)
pala : a weight (23)
palala : sesame-based confection (43)
palas : *Butea monosperma* (110)
palasa : *Butea monosperma* (111)
palika : a measure (21)
palla : weight measure (40)
palledar : labourer (37)
pan : trade, barter (16)
pana : a coin (22)
pancamrita : five-item fruit mix (161)
panch-pallavas : five sacred twigs (147)
panchagavyas : five products of the cow (157)
panchangaula : castor (62)
panicha : partly-dried coconuts (33)
panis : traders (16)
parangi-mara : papaya (115)
parijāta : a sacred tree (134)
parika : stuffed deep-fried snack (159)
pariksha : test (173)
parkhi : oilseed probe (29)
parna : *Butea monosperma* (111)
parpata : crisp. salty circles (43, 158)
parwal : a gourd (162)
pasai : leafy form of rai (q.v.) (54)
pat : jute plant (89)
patola : a dyed fabric (170)
patravalli : leaf plate (146)
patrika : stuffed wheat flour cake (159)
patta : fibre (89)
pecana : grain-cleaning operation (13)
peepal : *Ficus religiosa* (135)
peria-nangu : *Mesua ferrea* (96)
peshana : to grind (207)
phala : fruit, uncultivated produce (160, 161)
phalia : cotton (47)
phulwara : *Diploknema butyracea* (102)
pila : yellow (31)
pilu : yellow (102)
pilu : *Salvadora* spp. (102)
pinari : *Sterculia foetida* (106)
pinda : ancestor offering (44, 141)
pinnai : *Calophyllum inophyllum* (97)
pippala : *Piper longum* (14)
pirwa : variety of sarson (31)
pisa : *Actinodaphne hookeri* (103)
pitha : a bodily humour (172)
pitr : ancestor spirit (140)
polika : stuffed wheat confection (158)
polli : *Carthamus oxyacantha* (170)
pongal : a festival (148)
pongam : *Pongamia pinnata* (93)
Prakrits : Sanskrit dialects (20)
prana : life force (143)
pratapta : roasted meat (159)
priyanger : *Prunus mahaleb* (164)

priyangu : *Aglaia elaeagnoidea* (182)
priyaka : yellow *Shorea robusta* (?) (12)
priyala : *Chironji sapida* (158)
pucca : bigger; better finished (30)
puga : guild (18)
puja : worship ritual (143)
puli : tamarind, sour (111)
punarvana : *Boerhavia diffusa* (183)
pupalika : stuffed wheat confection (159)
pūrabhattaka : stuffed brinjals (160)
purana : stuffed wheat cake (159)
purika : cereal crisp (159)
purnakumbha : overflowing pitcher (142)
putti : volume measure (40)
pyru-ellu : winter sesame (45)

rabi : after-rain crop (7)
raga : fruit juice concoction (53)
ragi : *Eleusine coracana* (73)
rai : *Brassica juncea* subsp. *juncea* (30)
raida : *Brassica juncea* (51)
raita : a curd-based dish (161)
rajasik (a) : dynamic temperament (161)
rajika : rai (q.v.) (53)
raktapushpa : *Bombax ceiba* (109)
raktasāli : red rice (80)
rana : variety of sarson (q v.) (31)
rasala : mango (112)
ramtil : niger (64)
ratanjyoti : *Jatropha curcas* (107)
rati : *Abrus precatorius*, a weight (23)
ravana-malika : *Annona squamosa* (?) (116)
rayana : *Amoora rohituka* (98)
razai : quilted coverlet (109)
reh : sodium carbonate (166)
revu : port (154)
rishi : sage (136)
ritha : *Sapindus emarginatus* (164)
roghan : bodied safflower oil (170, 240)
roji : cotton variety (48)
rumal : cloth, handkerchief (170)
rum-kurthi : soyabean (70)
ruvuka : castor (62)

sadhi : safflower (65)
safed : white (51)
safed-simul : *Ceiba pentandra* (110)
sagwan : teak (111)
sajji : alkaline (165)
Saka era : starting 78 years after A.D. (20)
sakuli : a sesame-rice confection (43)
sal : *Shorea robusta* (99)
salai : oil press (209)
sali : winter rice (80)
salmali : *Bombax ceiba* (109)
sametani : brush on oil-mill (211)
samita : stuffed wheat flour cakes (159)
samudra : ocean (47)
samudranta : cotton variety (47)
samyava : fried barley (157, 159)
sannyasin : ascetic (141)
santhe : primary market (29)
santhra : *Citrus sinensis* (114)
sapota : *Manilkara achras* (116)
sarada : autumn rice variety (79)
saradithru : a season (11)
saranjam : evaluation (224)
sarira : *Ichnocarpus frutescens* (164)
sarisha : toria (q.v.) (51)
sarpagandha : *Rauwolfia serpentina* (183)
sarshapa : *Brassica* spp. (53)
sarson : *Brassica napus* var. *napus* (30)
sarson-ka-saag : leaves of the above (53)
sastika : rice variety (79)
sasyam : a grain (83)
sasyam-visesha : a remarkable grain (83)
satakara : mango (112)
satamana : a weight (22)
satta : a weight (34, 40)
sattvik (a) : reflective temperament (161)
savari : *Bombax ceiba* (155)
schit-ellu : sesame (45)
seer : a weight (23, 30)
semul : *Bombax ceiba* (109)

seohan : *Eruca sativa* (32, 51)
ser : a weight (23)
setthi : rich moneylenders (17)
setti : merchant (154)
shala : *Shorea robusta* (99)
shalya : surgery (171)
shanwar : Saturday (153)
sharifa : *Annona squamosa* (115)
shashi : a season (11)
shastika : rice variety (79)
shigru : *Moringa oleifera* (177)
shikakai : *Acacia rugata* (164)
shraddha : death anniversary (140)
shresthin : rich moneylenders (17)
shroff : banker (30)
siddartha : sarson (q.v.) (53, 55)
simanta : hair-parting ceremony
simul : *Bombax ceiba* (109)
sirish : *Albizzia lebbeck* (211)
siru nangu : *Mesua ferrea* (96)
sitaphal(a) : *Manilkara achras* (116)
soma : exhilarating plant juice (138)
som(a)raji : *Vernonia anthelmintica* (108)
somwar : Monday (153)
soru : food, rice (79)
sreni : guild (17, 18)
sriphala : coconut (142)
srni : sickle (13)
stamba-kari : maize (83)
sthivi : a granary (13)
subuki : a fish (158)
suhali : wheat cakes (157)
sukha : dry coconuts (33)
surpa : winnowing tray (148)
suvarna : a weight (23)
svami : religious functionary (19)
sveta : white (53)
sveta-salmali : *Ceiba pentandra* (110)
swayamvara : trial of suitor skill (138)

tabashiri : bamboo manna (183)
taila : oil (163, 164)
taila-ghānaka : oil press (20)
tajri : nostril oil (141)
talasarja : *Shorea robusta* (12)
tallita-kari : fried spiced meat (159)
talna : deep-fat frying (161)
tamal(a) : *Garcinia morella* (102)
tamasic : courageous, impatient nature (161)
tamela : *Garcinia morella* exudate (145)
tandula : rice (79)
tanghedi : *Cassia auriculata* (230)
tanki : volume measure (41)
tapta masha : trial by ordeal (141)
taptavyaji : over-measure (23)
taramira : *Eruca sativa* (31)
tarbuza : watermelon (113)
tarwar : *Cassia auriculata* (230)
tatliya : anointing oil (141)
tejpat : *Cinnamomum tamala* (182)
teli(ka) : oil miller (153, 208)
telia : oily (170)
ten : south (56)
thalli : *Actinodaphne hookeri* (103)
thay : tea (92)
then : honey (56)
thenga-ennai : coconut oil (210)
thengai : coconut (56)
thirikaiy-attam : oil mill (209)
thumba : *Citrullus colocynthis* (112)
tilabhuj : rite involving sesame (44)
tilahomi : rite involving sesame (44)
tilaka : of/from the sesame (207)
tilanjali : final goodbye (140)
tilaparpata : parpata (q.v.) of sesame (44)
tilapishāka : oil-miller (17, 21)
tilaprada : rite involving sesame (44)
tilasuayi : rite involving sesame (44)
tilavapi : rite involving sesame (44)
tilavikrti : vegetable dish with sesame (44)
tillanna : sesame cakes (140)
tilodana : sesame-rice dish (43)
tilodvarti : rite involving sesame (44)
tintidika : tamarind (111)
tirahl : tree press (240)

tirimo	: tree press (240)
tita-pat	: *Corchorus capsularis* (89)
togai	: peacock (24)
tola	: a weight (23)
tola	: weighman (37)
tora	: variety of sarson (q.v.) (31, 51)
toria	: *Brassica napus* var. *napus* (31)
triphala	: three-component mixture (164, 177)
trittiya	: three-day observance (137)
tula	: a balance (24); a weight (13)
tundikeri	: type of cotton (47)
udumbara	: *Ficus religiosa* (146)
ukh	: sugarcane (209)
ukhli	: small mortar (209)
ulisi	: niger (64)
ulukhala	: mortar (207)
ulukhalka	: grinding (209)
uma	: linseed (60)
undi	: *Calophyllum inophyllum* (97)
upabhogas	: pleasures of life (163)
urad	: *Phaseolus mungo* (38)
ursya pupalika	: large omelette (160)
utkarika	: rice flour confection (159)
utrumaram	: oil press (209)
vada	: deep fried pulse snack (157)
vadara	: cotton type (47)
vadi	: shaped, fried snack (159)
vaha	: a volume measure (23)
vahana	: vehicle (80)
vaisya(n)	: trader caste (24)
vanaprastha	: forest dweller (141)
vanaspati	: hydrogenated fat (161)
vankadi	: curved piece in the oil press (212)
varsha	: a season (11)
varshika	: rice variety (79)
varta	: commercial activity (24)
vartika	: stuffed pancake (?) (159)
varuni	: a distilled liquor (144)
vasa	: *Acorus calamus* (?) (158)
vasanta	: a season (11)
vata	: *Ficus benghalensis* (138)
vata	: wind (162)
vataka	: deep-fried pulse snack (158)
vatari	: castor (62)
vatha	: body element (172)
vatika	: crisp-fried snack (159)
vattimaka	: meat balls in gravy (159)
vayu	: literally, wind (172)
vennai	: butter (46, 210)
venthenna	: oil from fresh coconut (232)
vesavara	: ground meat (159)
vibhitaka	: *Terminalia belerica* (110)
vidalapaka	: pulse preparation (159)
vidanga	: *Embelia ribes* (13, 164)
Viravalanjiyar	: a guild (19)
virinzi	: rice (79)
vranaropana	: wound-healing (183)
vrihi	: rice (79)
wadian	: shaped, fried snack (159)
waraka	: a volume measure (24)
yantiram	: oil press (209)
yantra	: machine (208)
yava	: barley (11)
yāvana	: foreigner, usually Greek (25)
yavashara	: potassium carbonate (165)
yentiram	: oil press (209)
yupa	: sacrificial post (146)

GENERAL INDEX

(Entries in the Glossary of Indian Words are mostly not repeated here)

Author Index

The author will be found on the page number shown just after his name. Thus V.K. Abraham appears on page 127 in Reference *144*, which occurs on pages 75 and 76 of the text.

ERRATA

Page	*Line*	*For*	*Read*
xii	3 from end	Technological Research Institute, Mysore.	Delete whole phase
26	Fig. 4	Arakimedu	Arikamedu
26	—do—	Trapobane	Taprobane
61	1	116*a*	116*A*
62	25	119*a*	119*A*
69	21	100*a*	100*A*
75	17	144*a*	144*A*
79	4	(See Map)	Delete whole phrase
106	4	hansome	handsome
108	11	nd	and
108	11	foeti	foetid
205	Centre	PART	PART C
222	6 from end	Table 23	Table 21
305	6	kerne	kernel
312	27	p. 301	p. 305
323	30	beettle	beetle
323	36	buty	butyl
324	11	Fruit pulp/s	Fruit pulp/S
333	7 from end	J11	J10
324	Col. 2, line 3	orkernel	or kernel
336	4 from end	J11	J10
341	7	Eastimates	Estimates
246	1	Harmondsworth	Harmondsworth,
349	8	*Acti*	*Actin*
367	10, right col.	sakuli	saskuli